THE INDIGENOUS FORESTS OF THE SOUTHERN CAPE

A LOCATION STUDY

by

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CHAPTER 1

THE SOUTHERN CAPE FORESTS: PROBLEMS, DEFINITION AND DELIMITATION

"A forest means different things to different people. To one it means raw material; to another food ... adventure ... fertility ... firewood ... To the conservationist it is always an aid, as much in the fight against erosion as in the quest for a durable water supply and a self-sustaining wildlife". (Kimble, 1960, p. 195).

Although applied to forests of tropical Africa, the above quotation represents the "subsistence" plight of indigenous forests over much of the globe in the past, and this includes Southern Africa and more specifically, the Southern Cape. More recent forest management aims follow two important ecological principles, that of a sustained yield and that of a multiple use (Haggett, 1979, p. 120). Much of the Southern Cape indigenous forests is nowadays managed on these two principles. Certain areas have been classified as productive forests, implying management on a sustained yield basis. Others are classified as protected forests, while smaller portions have been set aside for recreational, research and reconstruction purposes. Unfortunately quantified data on forest location and spatial variation patterns of the Southern Cape indigenous forests is scarce to non-existent, and it is the aim with this treatise to help fill this void.

1.1 Stating the Problem

The indigenous forests of the Southern Cape have played an important socio-economic role over the past two to three centuries, with an important impact on the local rural farming and broader urban settlement patterns. It also influenced the early settlement pattern of the Southern African interior as a whole. Likewise the impact of man has left its mark on the forests, which at least in parts are but remnants of former "glory". The importance of these reciprocal impacts can to some extent be gauged from past reports and publications, the more noteworthy and comprehensive being Brown (1887), Sim (1907), Phillips (1931 and 1963), Laughton (1937) and Von Breitenbach (1974). These publications can broadly be termed historically- to ecologically-descriptive accounts, with emphasis falling on the descriptive.

The aim with this treatise is not to provide yet another contribution towards describing the forests but rather to attempt to analyse and to explain forest patterns as they exist today. The forests however represent a complex ecosystem and any endeavour to explain such a system must take into account, as Hartshorne (1959, p. 38) puts it, "... the difficult problem of determining which of the myriad number of phenomena that vary areally should be selected for inclusion in a geographic study."

This poses the initial problem of what framework to choose within which to attempt the explanation of forest patterns. The present forests cover a specific area, yet they are considered to have been considerably larger in areal extent in prehistoric times and also directly before the advent of man 250 and more years ago. Axelrod and Raven (Werger, 1978, pp. 79 - 119) and Van Zinderen Bakker (Werger, 1978, pp. 133 - 142) broadly discuss the occurrence of forests in prehistoric times. Axeldrod and Raven intimate that the continent of Africa lay 15 to 18° further south some 75 - 55 million years ago and that forest occurred along the Southern Cape from the late Cretaceous until recent times. Both Axelrod and Raven and Van Zinderen Bakker however refer to problems in reconstructing the vegetation pattern, since little fossil evidence is available to substantiate distinct patterns for this period. Based on studies by Martin, Schalke and Klein, Van Zinderen Bakker suggests that both fynbos and forests expanded after the previous glacial period of the Holocene, from about 12 400 years B.P. onwards, as a result of continuously rising temperatures; but that this expansive trend was again reversed, because the higher temperatures induced a drier climate resulting in sand dune development along the coast line. Phillips (1931, p. 233) refers to extensive areas of present-day machia (fynbos) which revealed remains of "forest relicts" when examined under the microscope. Acocks (1975, p. 6) also implies extensive forest and scrub-forest retrogression within the past 450 years by the difference between his Map No. 1 (1 400 A.D.) and Map No. 2 (1 950 A.D.). The problem of forest retrogression induced by human impact, has been a worldwide one. Jackson (Henderson and Wilkins, 1975, p. 130) observed that only 53% of what he terms "potential rainforest area" was actually occupied by rainforest in Tasmania, the other 47% having again reverted to grassland, shrubland, scrub or mixed forest.

When applied to the Southern Cape indigenous forests, the initial problem therefore is:

<u>Which factors, both natural and human, are responsible for, and can possibly explain the location pattern of the present-day forests</u>.

The secondary question of whether the present-day forests were indeed very much larger some 400 years ago, deserves closer scrutiny as well.

Natural-causal factors are principally considered responsible for the forests to exist where they presently are, yet the impact of man, as a human-effect relationship, is considered to have brought about considerable change to the natural forest setting (Eyre, 1977, p. 5). The dichotomy between the terms "natural-causal" and "human-effect" relationships require closer definition from the start. Hartshorne (1959, pp. 49 - 51) distinguishes between "natural" and "human" factors, by "natural" implying factors, which are active independent of man. He however supports the view that nature and man cannot generally be separated, in fact, Hartshorne (1959, p. 79) concludes that dividing geographical topics into natural and human halves has "... proven detrimental to the purpose of geography", and with that to a scientific comprehension of the environment. Stoddart (1965, pp. 242 - 247) warns that Hartshorne's whole approach altogether fails as an analytical geographical tool. He proposes the use of the ecosystem-concept in geographical thinking, a concept which tends to stress non-human systems in its application.

For purposes of this treatise the intention is not to create a dualistic principle of a "natural" separated from a "human", but rather to make a distinction between the impact of physical non-human factors which actually explain the forests to exist where they are, and those human-induced factors, which are supposedly responsible for its retrogression. The latter factors are ones that cannot explain the occurrence of an indigenous forest in a specific location, yet they can be used to explain why a forest does not occur in an area where it should by nature be located. In this context such human factors can well be regarded as "causative" again (Hartshorne, 1959, p. 52).

The second basic problem concerns the method of approach, implying the methods whereby forest location patterns are to be expressed, analysed and explained. Previous researchers, already briefly referred to, contributed in recording often exhaustive details about the Southern Cape forests. These can broadly be classified into the following disciplines:

(a) Historically-descriptive accounts, which are based on early to late 19th century reports written by government officials, botanists and forest-conservators. Brown (1887), Sim (1907) and Phillips (1963) contain and are themselves outstanding examples thereof;

(b) structurally-descriptive accounts:
These mainly describe the floral composition of the forests, though normally for specific forest parts only. Sim (1907) and Von Breitenbach (1972, 1974) serve as good examples, though quantitive data is scarce or fragmentary;

(c) silvicultural treatments, which emphasise forest management practises for the purpose of maintaining or improving timber production in the long term and for purposes of forest conservation. Laughton (1937) and Von Breitenbach (1968) give examples of this approach, although their work applies to specific portions of the Southern Cape forests only;

(d) ecological studies, which are mainly localised studies of certain species of flora and fauna, usually systematically arranged. Examples of such studies are Phillips (1931), in which the author describes the ecology of the Knysna forests, the heartland of the Southern Cape forests; and

Geldenhuys (1975), whose study of the Kalander Yellowwood (Podocarpus falcatus) is probably the most comprehensive ecological account of a single forest tree species in South Africa to date.

These contributions all tend to emphasize the "descriptive" and the authors referred to, tend to acknowledge this fact. Phillips (1931, p. 99) mentions that the records available to him were fragmentary and were "... of purely historic or semi-sylvicultural interest only." Phillips (1931, p. 3) in fact introduces his work as "... a preliminary description..." of the forests. Werger, (1974, p. 309) though referring to the ecological accounts of a wider botanist circle, including Bews, Phillips, Bayer and Killick, mentions that their accounts are "... mainly of a non-formal, descriptive nature ...".

Virtually all existing publications are based on research work and data derived from state-controlled forests. This particularly applies to Laughton, Von Breitenbach and Phillips. State-owned forests comprise about two-thirds of the Southern Cape total (Von Breitenbach, 1974, p. 7), with most of the privately-owned forests being located on fairly level ground west of Knysna (Fig. 1).

Little to no published data is available on the privately-owned forests. Most of the publications concerned furthermore reveal the common tendency of describing the forest as an entity unrelated to its immediate and wider environment. Unfortunately the tendency thereby exists that the proverbial "Forest cannot thereby be seen or understood because of the trees". There exists a decided need to view and explain the forests objectively in their wider, more

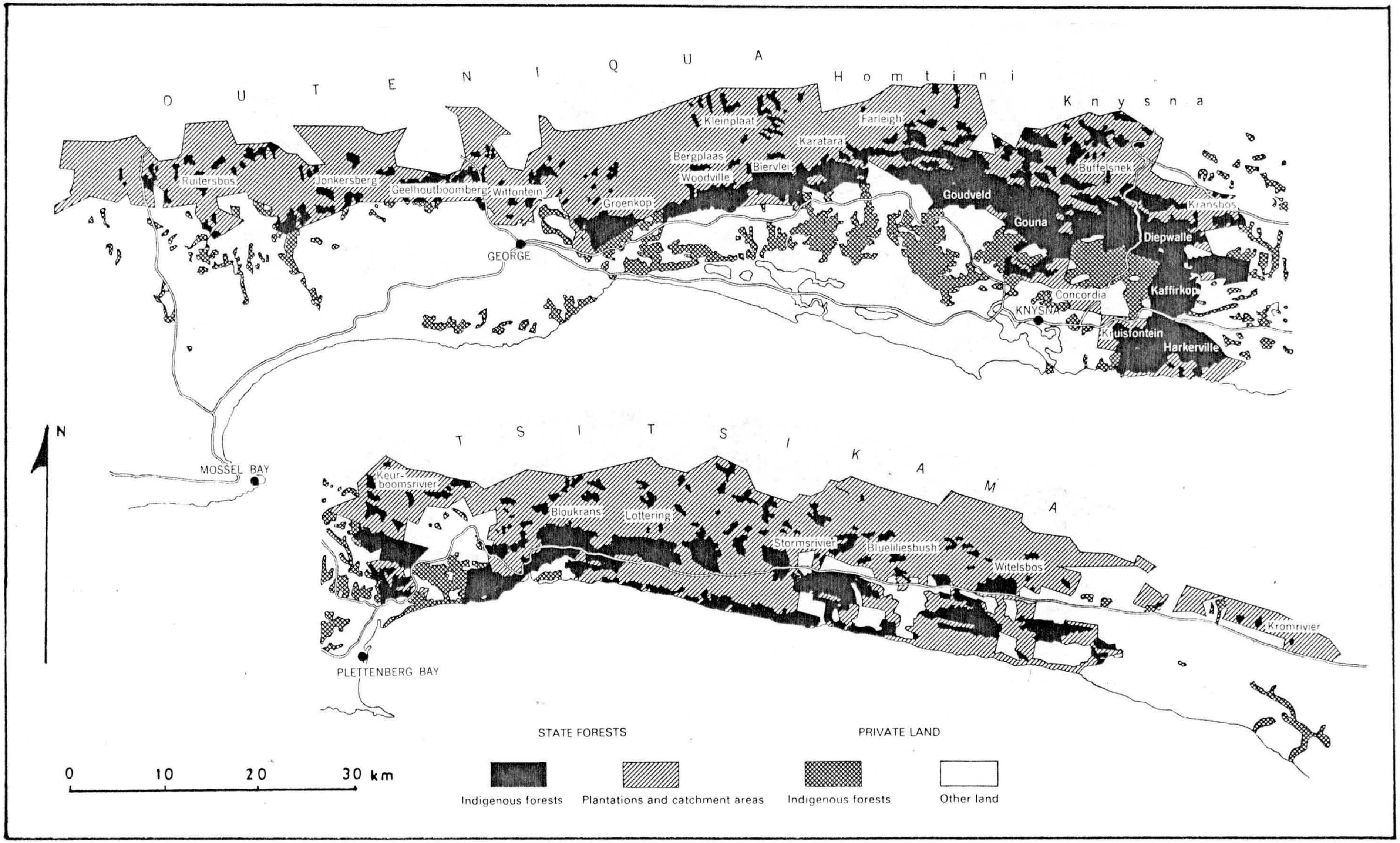

Fig. 1 The Southern Cape Indigenous Forest Location Pattern, featuring State and Private Ownership (after Von Breitenbach, 1974, p. 5)

regional setting, mainly from without. The research work referred to, though important it may be within its discipline, has its limitations in as far as an understanding of the broader forest concept is concerned. The Southern Cape indigenous forests have to be viewed as a functional ecological entity located within a much wider environment.

Concerning the more specific methods of approach, Orlóci (1975, p. 2) stresses the need for a more formal mathematical approach in vegetation research. He stresses the need for changing from what he calls "the old phytosociological approach", based on the art of "intuitive classifications" in favour of the "new approach", based on more formal methods, which include "... sampling and experimental design, data analysis and statistical inference." In order to involve the problem of methodology more specifically with geography, Stoddart (1965, pp. 242 - 250) also refers to the use of old methodology. Stoddart classifies the "old", as the basis, which, based on the work by Kant, Hettner and lately Hartshorne, attempted to raise geographical research work into an "exceptionalist" position, with a unique "integrating" function, "... synthesizing more specialised fields in space as history does in time." Stoddart suggests that the resultant methodology was "... at worst an exercise in the classification of areas";

the "new" approach, which, largely due to the influence of ecological methodology, links geographical research with modern scientific thought in, what Stoddart terms "system analysis", a term implying experimental and analytical research work.

It is hereby contended that the old approaches referred to tend to stress the description of phenomena and to classifying these into systems, but these lack the vitality evident in the new system of experimental, analytical, explanatory designs. However, the approach in this treatise is not one of a "Descriptive" versus the "Experimental-Analytical", with the latter being favoured. One has to be critical of the descriptive alone, because it does not explain anything, except the course of events. Experimentation is lacking. Experimentation alone, particularly nowadays through the use of statistical models is however equally fallible, mainly because of subjectivity of the researcher himself. The approach followed in this treatise is intended to be one inbetween these extremes. It involves a system being broadly described for the purpose of analysing and explaining forest locational patterns with the aid of modern statistical techniques and through experimentation.

Cochran and Cox (1957, pp. 1 - 2) emphasise the contribution which statistics provide to experimentation, both for planning "... their experiments and in drawing conclusions from the results." Experiments are carried out "... for the testing of hypotheses and the estimation of differences in the effects of different treatments."

No attempt has yet been made to evaluate the impact of any single factor or groups of factors on the location pattern of the Southern Cape indigenous forests as a whole, nor has any specific method been devised to quantify such impact locally. The aim with this study is to statistically and experimentally evaluate the location pattern of the local forests by a selected group of physical and human factors. Studies of this nature have already been conducted over extensive areas overseas, such as by Haggett (1968) in Southern Brazil. Haggett's work in fact served as broad basis for this study.

It is assumed that the present forest location pattern represents only portion of its natural potential. An attempt will therefore also be made to predict the potential or former extent of the local forests. In this respect the findings of Henderson and Wilkins (1975), that only 53% of Tasmania's potential rainforest area was actually covered by forest, is again referred to. By assuming that a forest imbalance may be evident in the Southern Cape as well, the aim would be to clarify factors responsible for such imbalance.

Why is it necessary to attempt this study? Why has it not been attempted before?

For once, South African forest research has until recently mainly been management or production orientated, with exotic plantation research claiming priority. Conservation research has not been lavished with capital funds, neither by the State nor private enterprise. Such development is understandable, because South Africa has been a timber importing country and has put its main resources behind striving for self-sufficiency in the timber industry.

Secondly, only within the past decade has particularly urban human pressure and demand necessitated the opening up of land areas hitherto virtually closed to man. The indigenous forests have become involved in a new multiple-use land utilisation scheme, implying the use of the forest for more than its wood products (Haggett, 1979, p. 210).

Thirdly, only within the past decade or two has scientific methodology been employing statistical methods of quantification. The computor age has enhanced the value of figures, at the expense of descriptive words.

Lastly, closely allied to the history of the local indigenous forests themselves, is the effect of the treatment meted out to the forests. The original human onslaught on the forests for one-and-a-half centuries until the turn of the century caused authorities to practically close the forests. This recessive impact meant a protective phase, which has only within the past decade or two gradually moved into the conservation phase indicated in the second point above.

1.2 Defining the Forest Concept

This treatise is centred around the term "indigenous forest", which, from the outset, requires closer definition. Unfortunately there does not occur a uniform definition of the term forest in South African scientific forest literature. The meaning of the term often appears to be taken for granted or, as Wellington (1960, p.84) puts it, "... is difficult to be precise in defining". Acocks (1975) uses plant association terms (veld types), but he does not define them except by species distribution. Grut (1965, p.1) uses the phrases "... the forests like those of Knysna..." and "... the true timber forests or high forests". Von Breitenbach (1974, p. 10) emphasises plant formation as a basic for forest classification, but simultaneously refers to tropical Africa for purposes of comparison: "... species which the Southern Cape have in common with their chief parent formation, the montane rain forest of tropical Africa".

Shimwell (1971, pp. 44 - 106) emphasises the application of both terms "plant formation" and "plant association" in vegetation classifications. For plant formation he applies the terms "structure" and "pattern", while "succession" and "climax types" describe the plant association. Hall, Johnston and Chippendale (1975, p. 4) emphasise structure when they describe the formation of forests in Australia as "... the development of denser tree and scrub layers until the tree canopy is more or less continuous and a forest is formed."

Greenway (1973, pp. 10 - 12) goes a step further, by distinguishing between "association", as the floristic unit, "formation" as "... a group of associations resembling each other in general physiognomy ..." and "formation types", based on the life form of the vegetation and upon the manner in which they grow together. He thereupon describes a forest as "... continuous stand of trees ... with crowns touching or intermingling and often freely interlaced with lianes. The canopy ... usually consists of several distinct layers or storeys ... The trees have simple ... boles." Gove (1961) defines forest as "... an extensive plant community of trees and shrubs in all stages of growth and decay with a closed canopy having a quality of self-perpetuation or of development into an ecological climax." Tinley (1975, p. 76) actually attributes two or more woody plant strata in his definition of forest. This is to distinguish it from woodland, which normally has a single storey, and so-called tree veld, which is normally unstratified. Webb (1978, p. 357), in his classification of the Australian rainforests, applies the term "forest" to vegetation in which "... canopy closure occurs at heights above an average of 9 metres."

For purposes of classifying the natural tree vegetation of the Southern Cape, the term "forest" is hereby contended to consist of:

(a) A fairly extensive <u>area</u>;

(b) a characteristic <u>vertical stratification</u>, consisting of at least two distinct storeys;

(c) a distinctive lateral or horizontal growth pattern of a <u>closed (crown) canopy</u>; and

(d) with a floristic element dominated by woody trees, the latter being defined by straight woody, normally-single boles.

These definitions and descriptions are accepted as the basis whereby forest in the Southern Cape are discerned from more open woodland, on the one hand, where tree crowns do not intermingle, and actual scrub, where the dominant flora consists of low shrub, which altogether lack tree qualities. The "open woodland" concept is evident in the Southern Cape mountains in rather small consocies of *Widdringtonia* cedars and *Protea nitida* (Waboom). Scrub or scrub-thicket occurs along the drier, sandy coast and is reasonably extensive. As far as the practical application of the "forest" classification in the Southern Cape is concerned, the definitions were applied verbatim for the whole study area, and did not represent any serious classification problems, as the transition from forest to scrubland, fynbos and grassland, as natural vegetation types, and to exotic pine and eucalypt plantations, was reasonably abrupt. This was particularly the case on the northern, mountainous forest fringes, where frequent fynbos fires have provided fairly abrupt demarcation lines. The transition from scrubland and scrub-thickets to forest, along the drier coastal belt westwards from Knysna, is however far less distinct and had to be resolved by local investigations.

It is at this stage necessary to refer to two distinct problems encountered in investigations of this kind. The first one concerns the use of aerial photographs to trace and confirm indigenous forest delimitation lines. The use of infra-red aerial photographs (Flight 499 of 1966) was thought to reveal more pronounced differences between vegetation types than monochrome photography, in particular differences between exotic plantations and indigenous forest.

While infra-red photographs show marked differences between conifers, such as pines (very dark), and broad leaved tree species (light), the differences in tone between indigenous forest vegetation and eucalypt plantations, both being broad-leaved species types, were hardly noticeable in places, so much so, that monochrome aerial photography had to be reverted to (Flight 499/1966 is also available in monochrome). A few errors on already demarcated forests were thereby detected. This problem applies mainly to eucalypt tree stands which do not feature straight demarcation boundaries and where boundaries merge with river or other natural features.

The second problem concerns successional indigenous forest stages, particularly in the smaller mountain forest patches. Many of these forest patches consist of distinct central forest portions, which are surrounded by ever decreasing, successional tree to shrub, to eventually open sclerophyll vegetation stages. These stages are particularly evident along the Outeniqua foothills north and north-west of George. These peripheral forest margins mainly consist of <u>Virgillia oroboides</u> consocies, which represent pioneer successional forest stages after repeated fire damage (Von Breitenbach, 1974, p. 196). As one moves away from the central forest core, the <u>Virgillia</u> trees tend to thin out into single-storeyed, open woodland, eventually to merge into fynbos of the <u>Berzelia</u> type to form typical scrub-thickets, before merging into fynbos veld as such. The question where a forest really starts and ends is not easily resolved, and the "forest" definition mentioned earlier, had to be rigidly applied.

1.3 <u>Delimitation of the Study Area</u>

The present indigenous forest location pattern serves as main consideration for the delimitation of the study area. Fig. 2 depicts the study area within its wider Cape environment and can generally be described as being bounded by the coast-line in the south, by the crests of the Outeniqua mountain range in the north and by the 22°05'E and 24°15'E meridians as respectively the western and eastern extremeties (Fig. 6).

The southern coast-line presents no problem. Forest occurs right up to the coast-line along the steep Tsitsikamma coast, thereafter just east of Knysna and then again south of George. This can be followed on the forest distribution maps (Figs. 1 and 6). Thirion (1965), in his study of the climatic types of the Southern Cape, also chose the coast-line as southern boundary for his study area.

The northern boundary in the present study also consists of a natural barrier, namely the crests of the Outeniqua range north of Mossel Bay, George and Knysna, thence eastwards as the Langkloof range, the Tsitsikamma range to finally culminate in the Kareedouw range. These folded mountain ranges run more or less parallel to the coast-line and provide a distinct watershed line between the drier Little Karoo and the moister coastal forest region (Fig. 3). The Outeniqua and Langkloof ranges are broken into and actually separated by the upper Keurboomsriver due north of Knysna thereby providing a somewhat indistinct watershed line. No marked forests occur along the north-facing slopes of the ranges concerned. Watersheds appear to be widely used as demarcation lines. Tait (1967), in his study of the northern aspects of the Outeniqua mountains, used this watershed line for delimiting his study area, in this case as his southern

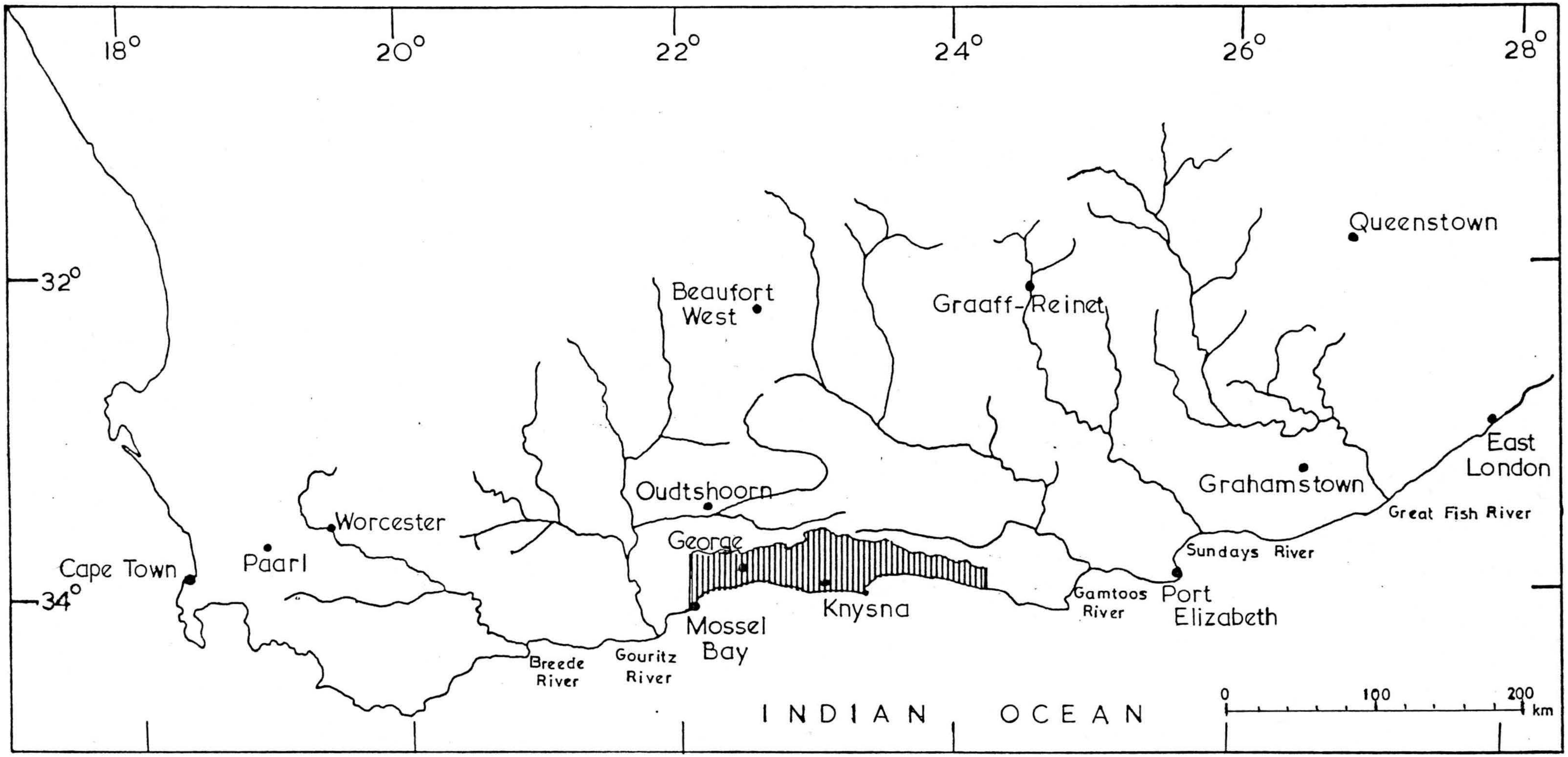

Fig. 2 The Southern Cape study area (which appears shaded)

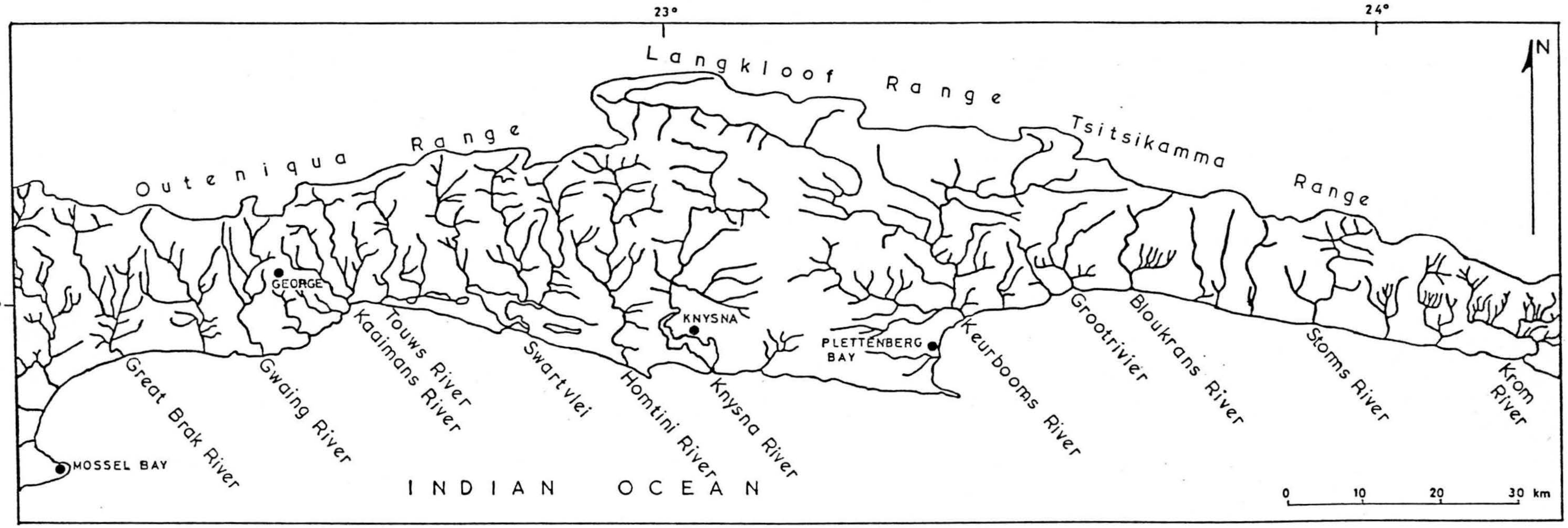

Fig. 3 The Southern Cape drainage pattern

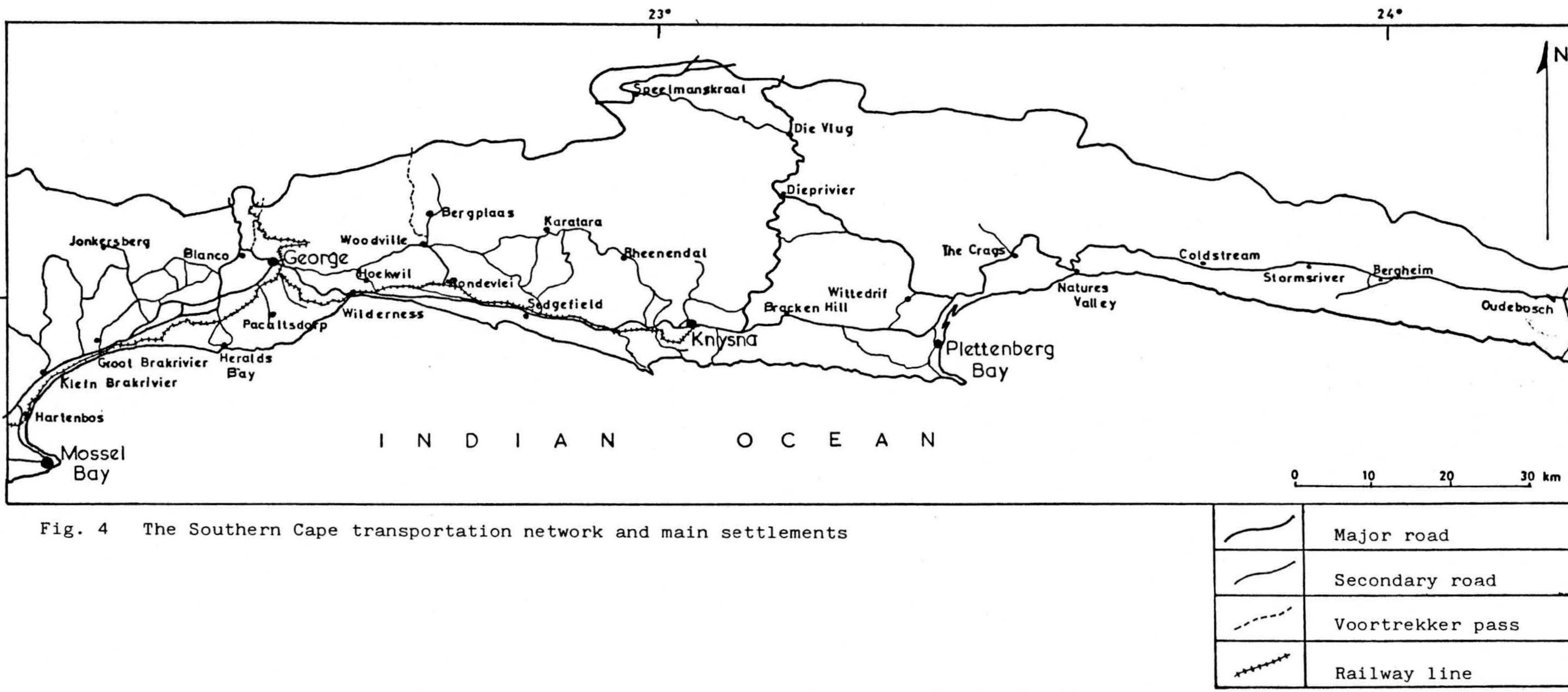

Fig. 4 The Southern Cape transportation network and main settlements

boundary. Von Breitenbach (1974, p. 5) uses the boundaries of state-owned forest land as his northern boundary (Fig. 1). The latter roughly follow the Outeniqua mountain watershed line, particularly from north of George to Knysna, and then again along the Tsitsikamma range, but there is little continuity in such boundaries. Wellington (1955, p. 3) in his delimitation of "Southern Africa", choses a watershed line, that between the Congo and the Zambezi, as a delimitation line.

The narrow eastern and western boundaries provided little difficulty, as the forests wane considerably in both directions. For the eastern boundary the 24°15'E meridian and for the western boundary 22°05'E were selected, on the grounds that in both cases only isolated, small remnant forests were hereby excluded, which were not regarded effectual. Both Tait (1967) and Thirion (1965) applied meridians as their western and eastern boundaries. Thirion's study area features 22°E by 26°E. Von Breitenbach (1974) does not feature distinct western or eastern boundaries in his forest distribution map (Fig. 1), but they roughly coincide with those depicted in Fig. 6.

The study area has a total surface area of about 4 500 km^2, of which about 650 km^2 (Von Breitenbach, 1974, p. 7) or 14,5%, is covered by indigenous forest.

1.4 Research Methods

The ensuing chapters consist of two main divisions, the descriptive answering to the what and where, and the analytical answering to the how. Whereas the descriptive leans heavily on published data and is thereby more formal, the analytical methodology and general approach is largely experimental, thereby less predictable.

The analytical methodology is largely based on research work done by Haggett (1968) on forest persistence in south-east Brazil and involves the following salient steps:

(a) The selection of geographical criteria, which is regarded as important in explaining the existing forest location pattern. The descriptive division referred to, aided such factorial selection;

(b) the mapping of such criteria and expression thereof in suitable factorial data form, thereby quantifying each factor into land area and forest area covered at a reasonable number of levels;

(c) the testing of such quantified data as to its statistical significance;

(d) the grouping together of individual factors into suitable factorial designs, the analysis of variance of each of such factors and their combinations being tested at both regional and local levels.

Alexander (1963, p. 588) stresses the importance of problem solving by spatial analysts by using such a statistical approach.

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CHAPTER 2

PRESENT LOCATION PATTERNS OF THE INDIGENOUS FORESTS OF THE SOUTHERN CAPE

2.1 Setting the wider Forest Scene

Before attempting an analysis and explanation of specifically local locational patterns, the forests need first of all be viewed in their wider global and continental setting.

South Africa is but poorly endowed with natural forests. A percentage forest cover of considerably less than 1% of the total land surface is frequently mentioned (Von Breitenbach, 1974, p. 2; Wellington, 1955, p. 301). When viewed in its global setting, this fact is substantiated. FAO Forestry Department (1978, pp. 6 - 7) divides the earth as a whole into 22 forest land-cover regions, based on "closed forest" land cover. "Closed forest" is therein defined as a tree cover of more than 20% and as such excludes open woodlands and savannah-type forests. It is significant that the continent of Africa, including the Middle East, include five of the least forested regions of the earth. These are, in sequence from the lowest upwards: North Africa, Southern Africa, the Middle East, East Africa and West Africa. Only Central Africa on the African continent features a high forest cover and is placed 16th. Canada, Brazil and the U.S.S.R. are respectively placed 20th, 21st and 22nd. The abovementioned setting must, however, not be viewed as a stable one. Zon (1961, p. 253) maintains that 25% of the earth's land area was at some time in the past covered by forest, but that man "... not only conquered, but exterminated beyond any possible chance of natural recovery ..." large parts thereof, and that only 15% of the original forest cover is left. Zon quotes Britain as having lost 95% of its original forest and North America 44% within the past three centuries.

The African continent, depicted on Fig. 5, mainly features tropical and subtropical, broad-leaved, evergreen high forest, to use a lengthy group term. The map clearly depicts the Southern Cape forests as the culmination of the southward spread of broad-leaved forest. Von Breitenbach (1974, p.8) refers to these forests as "... southern outliners of the tropical forest belt ...", although he does not classify the forests themselves as "tropical" by nature. The African forests have also undergone major change. Dumont (1964, p. 18) mentions that the equatorial rain forests of Northern Zaïre are not virgin forest anymore "... for it nearly always comprises secondary growth, re-established after a period of cultivation." Werger (1978, p. 159) describes the eastern forests phytogeographically as Afromontane, mainly consisting of dense forests, but also of grasslands and savannas "... which are possibly secondary ...". White (Werger, 1978, p. 506) maintains that forests are the only type of Afromotane vegetation found in the Cape.

The Southern African closed forests must be seen as consisting of different types. There is not full agreement on the use of terminology to distinguish between these types. Acocks (1975) classifies the Southern African forests into Coastal Tropical Forest, with the Knysna forest as example; Inland Tropical Forest, such as those of the Zululand interior and the Transvaal Drakensberg; and Temperate and Transitional Forest, such as those occurring along the Natal Drakensberg and thereafter mainly southwards along mountain slopes. Phillips (1931, p. 203) classifies the Knysna forest as Temperate-form of Subtropical Forest. Wellington (1955, p. 302) describes the Knysna forest as "... the largest area of temperate forest..." in Southern Africa. He classifies other forests into Subtropical Coastal Forests and Montane Forests, the latter obviously associated with forests located along inland mountain slopes. Laughton (1937, pp. 12 - 13) distinguishes between Mixed-Yellowwood and Broadleaved Forests, such as the Knysna forest, Coastal East Coast Forests and Subtropical Forests.

Even though the above terminology appears confusing, possibly even contradictory, the forest classifications broadly agree on the following three Southern African forest types:

(a) A Coastal Forest type, with a distinctive maritime impact;

(b) an Inland Temperate Montane Forest type, associated with cool, wet escarpment slopes;

(c) an intermediate Temperate to Subtropical High Forest type where forest as such frequently attains a distinctive climax development.

It is suggested that the Southern Cape forests have attributes of all three the above types, a fairly narrow, dry coastal forest, numerous very wet mountain forest patches, with the bulk of the intermediate forests belonging to the medium-moist high forest type. This broad classification is rather unique, because all three types occur within distances of a few kilometres from the coast-line. The more northern forests in Natal, the Eastern Transvaal and Eastern Zimbabwe occur at distances often exceeding 100 kilometers from the coast-line (Fig. 5).

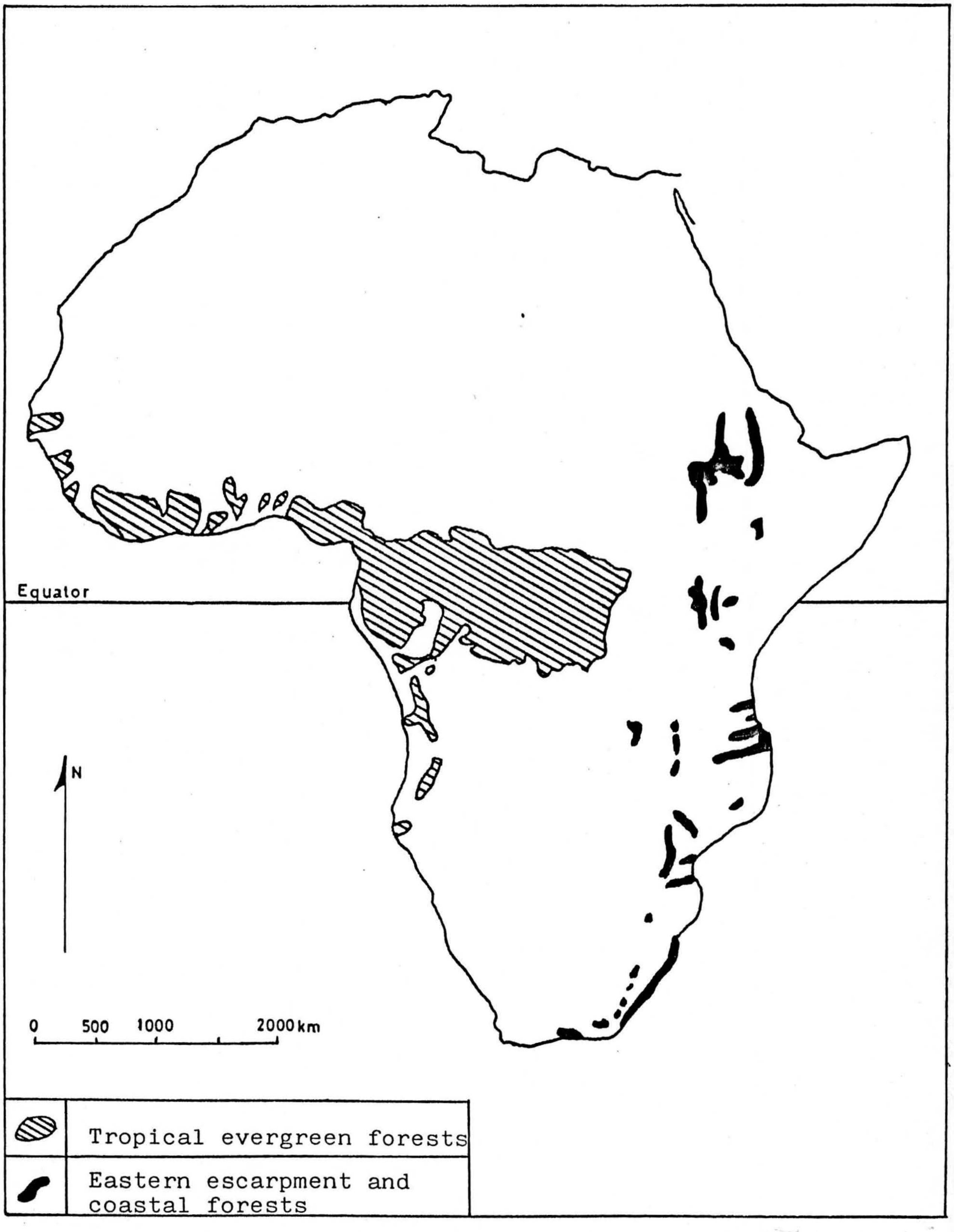

Fig. 5 The hygrophytic forests on the African continent (Linton, 1961)

The Southern African indigenous forests are further typified by their floristic composition and the dominancy of specific tree species, alternatively the phasing out of others (Von Breitenbach, 1974, p. 10). Von Breitenbach mentions that of 300 tree species common in the Natal and Transkei forests, about 250 occur in the Eastern Cape forests, while only 125 are found in the Southern Cape forests. Phillips (1931, pp. 161 - 164) reveals similar figures. Von Breitenbach (1974, p. 16) however lists another 15 tree species found entirely endemic to the Southern Cape. With that attention is focussed on the Southern Cape indigenous forests themselves.

2.2 The Southern Cape Forests

The Southern Cape indigenous forests are not entirely uniform in themselves. A number of distinct forest types are distinguishable. Phillips (1931, pp. 194 - 199) bases his classification on moisture regimes and distinguishes between three main forest types, viz. a dry, medium-moist and moist forest type. He, however, indicates a habitat modification in each type, based on overall tree height. Laughton (1937, p. 68) acknowledges Phillips main types, but expands upon them by recognising five basic types: dry, medium-moist, moist, wet and the Blechnum (very wet) types. Von Breitenbach (1974, p. 18) recognises as many as eight basic types, based on temperature and moisture zones, viz.:

(a) The hot and dry zone: which feature very, very dry scrub; very dry scrub-forest; and dry high-forest;

(b) the temperate-humid zone: which feature medium-moist high-forest and moist high-forest;

(c) the cold and wet zone: featuring wet high-forest; very wet scrub-forest; and very, very wet scrub.

In Von Breitenbach's forest type classification the first and last are termed scrub, or scrub-thicket by the earlier definition of the term "forest", and cannot therefore strictly feature as a "forest type". However, Von Breitenbach emphasises the fact that scrub types are frequently a result of previous over-exploitation of a higher forest vegetation type, and thereby represent, what he terms successional "secondary" scrub. Kimble (1960, p. 196), with reference to Aubréville, emphasises that in a dry Africa the extensive dry type of forest is particularly important in preserving "... the environment from a deterioration that would aggravate the effects of the severe climate", thereby attaching importance to particularly drier successional forest phases.

Phillips, Laughton and Von Breitenbach all make floristic distinctions between their respective forest types. Forest types are thereby distinguishable by plant indicators, and, although Phillips (1931) and Von Breitenbach (1974) in particular, present lengthy discourses on this topic, the floristic distinction can be summarised according to Phillips (1931, pp. 195 - 199) as follows:

> Dry forest type: Absence of typically wet-type species such as Cunonia and Platylophus; presence of typical dry-type tree stratum featuring Pterocelastrus and Cassine as typical examples; presence of a thorny sub-stratum; overall a decrease in canopy height with increase in degree of dryness.

Moist Forest Type: Absence of dry-type species already mentioned; presence of Cunonia and Platylophus as tree stratum, and Alsophila (tree ferns) as sub-stratum; overall, a decreasing canopy height with increase in degree of moisture.

Medium-moist Forest Type: Virtual absence of typical dry- and wet-type species already mentioned; an increasing presence of Olea capensis subsp. macrocarpa and Podocarpus latifolius in the tree stratum; an optimum canopy height or climax is reached here.

The Southern Cape forests must be seen for their direct usefulness, mainly from a historical context. Timber, notably stinkwood and yellowwood, has been the main utility product in the past. Man has however cleared large forest tracts for cultivation purposes, has used the forest as hunting grounds, for shelter for his domestic animals and to a lesser extent for direct grazing purposes (Von Breitenbach, 1974, pp. 36 - 42). Human demand outweighed growth supply, resulting in the reduction of timber supplies. Extensive areas were thereupon "closed" and protected until a decade or two ago. Only within the past 15 years have the forests under state control been managed afresh under a more rigid conservation management system, involving, as Von Breitenbach (1974, p. 42) puts it, "active rehabilitation". This system includes protection, reconstruction, controlled exploitation and utilisation of the recreational potential of these forests. Most of the privately-owned forests still appear to be exhausted, most of these even of potential timber supply. But private forests have recently also been incorporated into this conservation scheme, namely by restrictions placed by legislation. Government

Gazette (1971) was the first to declare White Milkwood, Sideroxylon inerme, protected on all private land in the Cape Division. This was followed by Government Gazette (1974-a) declaring the same tree species protected on private land throughout the whole country. Simultaneously all yellowwood trees, Podocarpus, were declared protected in the Province of Natal. Government Gazette (1976) lists all yellowwood species as protected throughout South Africa, together with such Southern Cape tree species as stinkwood, terblans, tree fern and white milkwood. The significance of legislation as a recent conservation tool is furthermore evident from the promulgation of Government Gazette (1974-b). It features 23 private properties, all located in the Southern Cape from north of Mossel Bay to east of Knysna, declaring all natural forests thereon as protected. This means that the land-owner concerned may not fell trees in his own forests.

The usefulness of the forests must, finally, also be seen as affecting their immediate environment (Tyson, 1971, pp. 15 - 23). The buffer effect of the forests between fairly populous, economically productive and viable coastal lowlands, and the vast, uninhabited, unproductive mountain fynbos, is important in more than one respect. The forests prevent excessive soil erosion, retain and filter water resources and act as barrier to mountain fynbos fires, although they are damaged in this latter process. The present broad land utilisation pattern of the Southern Cape involves an initial narrow coastal, sandy wasteland, followed inland by strips or belts of respectively mixed agriculture, exotic tree plantations, the natural forest belt itself, which culminates in extensive mountain sclerophyll.

2.3 The Indigenous Forest Area

The Southern Cape indigenous forests comprise an area of about 65 000 ha (Von Breitenbach, 1974, p. 7), of which 43 000 ha is situated on state-controlled forest land, the remainder being owned by private people. However various sources quote different figures to the above. Table 1 features six sources, which have been expressed in hectare for convenience sake, but which show a range from 42 900 ha to 72 000 ha. This obviously leads to the question: What is the actual indigenous forest area? Unfortunately none of the above sources can be traced back to a calculated origin. This areal problem must however be intimately concerned with the question: What have the authors concerned regarded as indigenous forest?

The virtual absence in literature of a calculated area for the indigenous forests of South Africa as a whole, stresses the relative unimportance placed on the areal extent of our forest heritage. Sim (1921, p. 4) already states in this regard: "The area of actual forest in South Africa has never been clearly shown, and through various causes is easily misjudged. Private forests have, in most cases, never been separately surveyed ...; and even in regard to the crown forests other particulars are more easily obtained than the area of the actual forest." Sim thereupon estimates the total area of high forest in South Africa to be 222 600 ha (Table 2), but he also mentions a scrub forest area totalling 745 000 ha, thus a forest area total of 967 600 ha. From Table 2 Bosman (1956) and De Villiers (1951) are seen to quote fairly high indigenous forest areas of 374 330 ha and 380 400 ha respectively, while Lückhoff (1973) and Grut (1965 and 1975) only quote areal values of 255 000 ha, though Grut (1975, p. 12) admits that "... data are very approximate, especially as regards the natural forests."

TABLE 1 VARIATION IN THE SURFACE AREA OF THE INDIGENOUS FORESTS OF THE SOUTHERN CAPE

SOURCE	SURFACE AREA (ha)
1. Laughton, 1937, p. 14	51 800 *
2. Count Vasselot, in Laughton 1937, p. 24	42 900 *
3. King, 1941, p. 27	61 916 *
4. Lückhoff, 1973, p. 20	45 000
5. Von dem Bussche, 1973, p. 1	72 000
6. Von Breitenbach, 1974, p. 7	65 000

* Areas converted to ha.

TABLE 2 VARIATION IN THE SURFACE AREA OF THE INDIGENOUS FORESTS OF SOUTH AFRICA

SOURCE	SURFACE AREA (ha)
1. Sim, 1921, p. 7	222 600 *
2. Sim, 1927, p. 44	314 690 *
3. Neethling, 1943, p. 4	319 300 *
4. Bosman, 1956, p. 2	374 330 *
5. De Villiers, 1951, p. 3	380 400 *
6. Adamson, 1956, p. 385	242 800 *
7. Grut, 1965, p. 1	255 000
8. Grut, 1975, p.12	255 000
9. Lückhoff, 1973, p. 268	255 000

* Areas converted to ha.

It is again not clear what the authors concerned have specifically regarded as indigenous forest. De Villiers (1951, p. 3), for example, quotes an "exploitable" forest area, Bosman (1956, p. 2) uses the plain term "indigenous forests", Neethling (1943, p. 4) speaks of "high" indigenous forest, Adamson (1956, p. 385) quotes "true" forest, while Lückhoff (1973, p. 268) quotes "true high forests". It appears as if to date there is no authoritative figure representing the area of indigenous forests in South Africa.

With the previous comment in mind, the determination of a fairly reliable surface area of the Southern Cape indigenous forests was regarded of the first priority. The aim was not to become involved in intricate and extremely detailed areal measurement techniques, but rather to devise a practical and workable areal measurement pattern, which would later on be useful for testing the effects of various factors on the indigenous forest location pattern. Simplicity but effectiveness were the key words. An indigenous forest distribution map, drawn to a scale of 1 : 250 000, appears in Von Breitenbach (1968, p. 2). This map also appears on a smaller scale (scale unknown) in Von Breitenbach (1974, p. 5; Fig. 1). Von Breitenbach's older map was chosen as basis for compiling a Southern Cape forest distribution map for the explicit purpose of determining a reliable forest area. The reasons for preferring the older map to the newer one (Fig. 1) are that the older map is drawn to a manageable scale of 1 : 250 000 (Fig. 1 would have to be represented on a much larger scale); indigenous forest distribution is the same on both maps; Fig. 1 features a large number of forest areas obliterated by place names; and both maps showed incompleteness as far as the northern study is concerned.

Von Breitenbach's (1968) map was checked against the 1 : 50 000 topographical series as well as aerial photographs (Flight 499/1966). Minor alterations and additions were made along the coastal regions and along the slopes of the upper Keurboomsriver valley. The latter forest patches do not feature on either of Von Breitenbach's maps. Fig. 6, conveniently reduced in scale (also refer to Van Daalen, 1980, Map 1), was retained at the standard scale of 1 : 250 000 for purposes of factorial analysis.

For purposes of determining a reasonably accurate and workable figure for both the total study area and the indigenous forest area, a separate map was drawn, also to the standard 1 : 250 000 scale, and covered with a grid system, each unit of which measured one minute by one minute. Each unit comprised a calculated area of 281,667 ha, calculated as follows:

1 unit = 6,106 mm (longitude) by 7,381 mm (latitude)

= 45,0666 mm^2

45,0666 mm^2 converted = 281,667 ha

The grid map was transposed over the forest distribution map and the forest cover was carefully estimated and recorded in eighth-values on the grid map, the figure 8 indicating complete indigenous forest cover, the figure 4 indicating half coverage, etc. This grid map was initially intended to roughly estimate the indigenous forest area, but it was subsequently used extensively as an indigenous forest area control map for factorial analyses. Fig. 7 serves as a sample of this grid map. The eighth-values

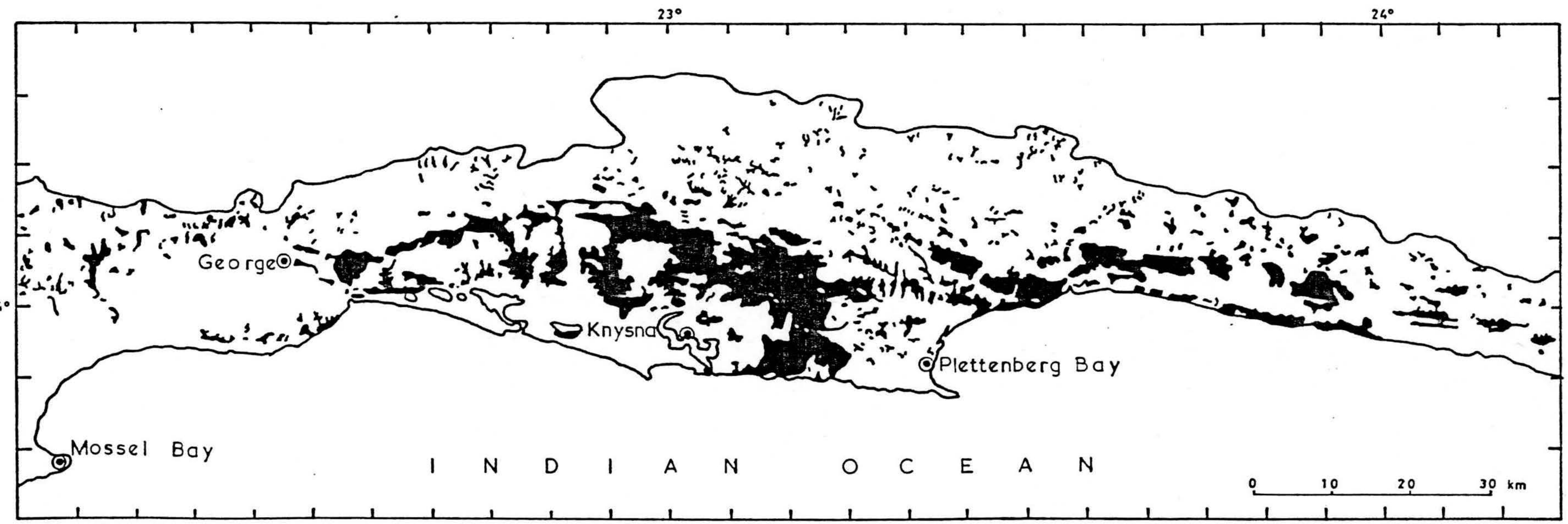

Fig. 6 The distribution of indigenous forests of the Southern Cape (adapted from Von Breitenbach, 1968)

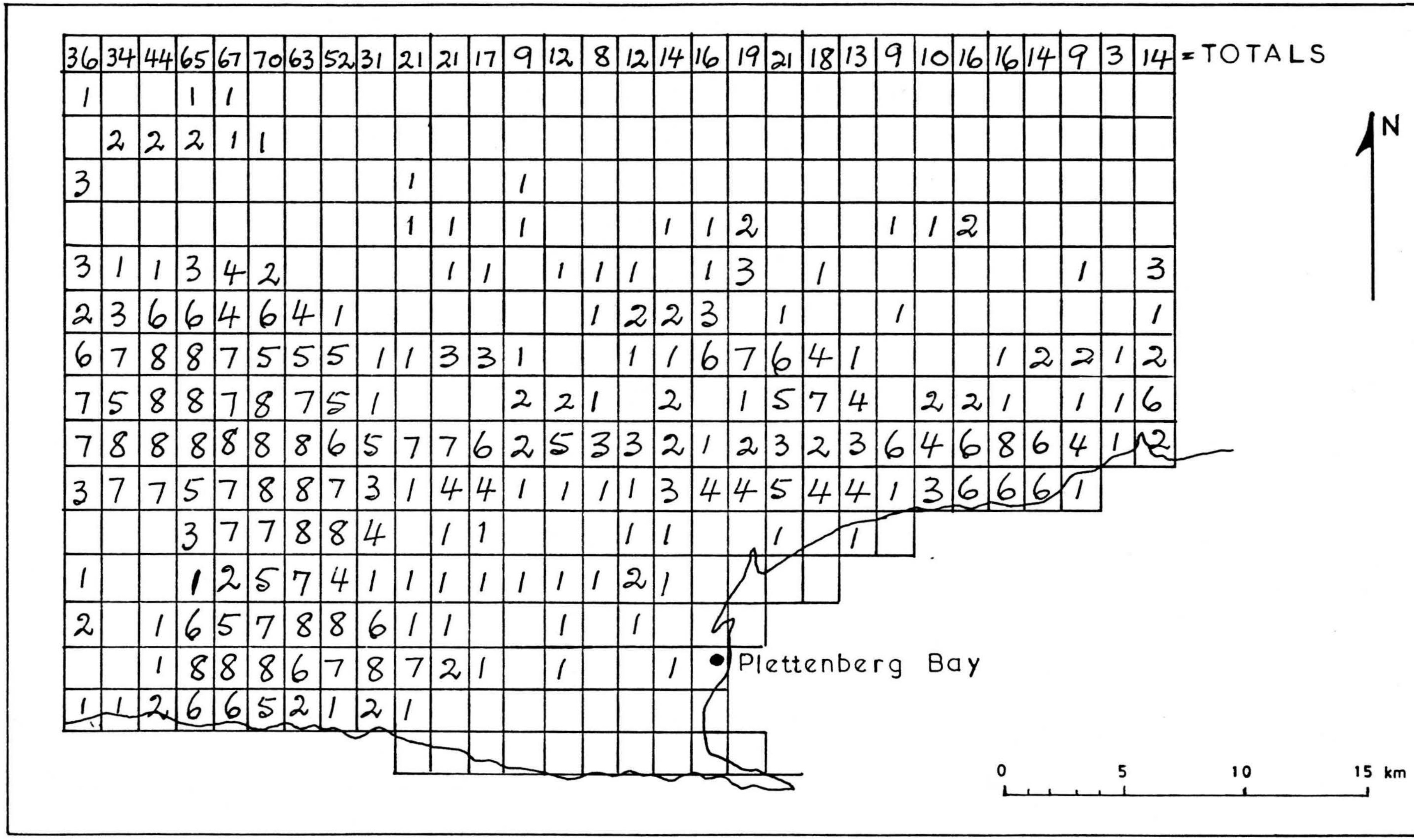

Fig. 7 The indigenous forest distribution control map - a sample.

totalled 1 866 eighth unit values, therefore 233,3 full units, with a total forest area of 65 713 ha. This area figure compares well with the 65 000 ha mentioned by Von Breitenbach (1974, p. 7) and was accepted as areal basis for purposes of this study. The above treatment theoretically means that forest patches up to the size of 17 ha (being one-sixteenth of a grid-unit) would be neglected. This was however not the case, since a combination of smaller forest patches within or even closely surrounding a unit square, were accorded a combined eighth-valuation.

The total land area of the study area comprised 1 586 full grid-units. However, in this case a total surface area of 447 579 ha was accepted as basis for all subsequent treatments, based on the average of five separate planimeter measurements. According to the grid map the total surface area would have been calculated as 446 724 ha, featuring a discrepancy of a mere 0,2%. This, in effect, means that 14,7% of the Southern Cape study area is covered with indigenous forest.

The above discussion emphasises the broad forest areal pattern, without referring to the quality of the forest stand itself. It is perhaps fitting to quote King (1941, p. 30) in this latter regard:

> "... the surprising feature is that they (the Southern Cape indigenous forests) have lasted so long. About 19% are still regarded as exploitable, 56% have been overworked and 25% reduced to kreupelbos which will take centuries to recover."

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CHAPTER 3

THE FOREST ENVIRONMENT: PHYSICAL LANDSCAPE

The aim with a discussion of the physical forest landscape is twofold. It provides the framework for an ecological structure of which the indigenous forest is part, but such a discussion already serves to indicate the impact of specific environmental factors on the forest location pattern as a whole. The intention is to follow such a discussion up with the selection of the more significant of these factors, to test their validity and degree of impact, and to endeavour to thereby explain the indigenous forest distribution pattern.

As far as the physical landscape is concerned, Tyson (1971, pp. 3 - 14), Phillips (1931), Laughton (1937) and Von Breitenbach (1968) distinguish and list geology, physiography/topography, climate, soils and vegetation as the principal components dominating the George-Knysna scene. From the outset it is significant though that the above factors should not be viewed in isolation, but on their combined impact on the forest distribution pattern. Wellington (1955, p. 301) lists moderate temperatures, adequate soil and moisture as basic preconditions for an indigenous forest type. He follows this by clarifying the climatic requirements as "excess rainfall over transpiration and evaporation", temperature largely controlling the forest types, while the soils control the type of root system accommodated (Wellington, 1960, p. 84).

3.1 Geology

Wellington (1955, pp. 11 and 105) emphasises the significance of what he terms "rock character and structure" in the formation of physical features.

He stresses the importance of the folded belt and coastal foreland as the outstanding physiographic element of the Southern Cape. Du Toit (1926, p. 14) also stresses the Cape folded belt and what he terms the "tertiary peneplain" as the dominant physiographic feature of the Southern Cape, influencing soil formation, climate, vegetation types and human usage.

The geological succession in the Southern Cape includes stratigraphic deposits ranging from Archaean formations to the Cainozoic (Tyson, 1971, p. 3). This includes pre-Cape deposits and subsequent granite intrusions; Table Mountain sandstone and Bokkeveld shales of the Cape Supergroup; followed by Enon deposits of the Cretaceous period as well as recent unconsolidated alluvial, aeolian and marine deposits of the Quaternary (Fig. 8).

The oldest deposits, dating 900 to 600 m.y. ago (Trustwell, 1977, p. 96), occur in the George area and are generally referred to as the Malmesbury deposits in older literature (Rogers, 1905, pp. 33 - 34 and Du Toit, 1926). Truswell (1977, p. 93) however mentions that "... there is no evidence to indicate whether or not these rocks are in fact time-correlatives of the Malmesbury ..." and more recent publications refer to these deposits as the Kaaimans Formation (Toerien, 1979, p. 2) and the Kaaimans Group (Kent, 1980).

The Kaaimans Group is largely metamorphosed by Pre-Cape Granite/Gneiss intrusions about 610 to 505 m.y. ago (Truswell, 1977, p. 96) giving rise to phyllites, quarzites, hornfels and schist deposits (Toerien, 1979, p. 2). Both these groups are intermittently exposed along the plateau from north-west of Knysna to north of Mossel Bay (Fig. 8). Toerien (1979) refers to the Granites as the Maalgaten Granite.

The Table Mountain Sandstone is shown as a single formation on Fig. 8. It dominates the northern study area from east to west. The TMS group is however divided into five local formations (Table 3), of which the Peninsula and Tchando formation are particularly dominating. The Peninsula formation is the thickest, up to 2 700 m, and the most massive. It dominates the steeper Outeniqua mountain ridges and forms the northern boundary of the study area.

The Tchando formation is exposed along the foothills of the Outeniqua range, particularly north-east to north-west of Knysna and is of particular interest, since it covers most of the indigenous forest heartland. The Cedarberg, Kouga and Baviaanskloof formations only cover narrow bands mainly along the Tsitsikamma Coastal platform and thence north-west into the Keurboomsriver valley. Apart from the Cedarberg and Tchando formations, which contain narrow shale bands, the TMS features medium to coarse grained sandstone.

The Gydo is the only local formation of the Bokkeveld group (Fig. 8, Table 3). It is exposed in narrow bands associated with the Baviaanskloof and Kouga formations of the TMS, which it overlies. This formation is distinctly argillaceous and therefore weathers to a fine clay (Toerien, 1979, p. 4; Hamilton and Cooke, 1965, p. 121).

The Cretaceous Enon deposits (Fig. 8) are found along the coastal plain north of Mossel Bay, at Knysna and Plettenberg Bay. They are generally encountered

TABLE 3 THE GEOLOGICAL FORMATIONS AND LITHOLOGY OF OF THE CAPE SUPERGROUP (Toerien, 1976; 1979)

SUPERGROUP	GROUP	FORMATION	APPROX. THICKNESS	LITHOLOGY
Cape	Table Mountain	Peninsula	2 700 m (max.)	Mainly medium-grained sand-stone and quartzites massive.
	(TMS)	Cedarberg	45 m	Black shale bands inter-mixed with sandstone.
		Tchando	330 m	Fine to coarse grained sand-stone with subordinate shale bands.
		Kouga	400 m	Medium to coarse-grained sand-stone.
		Baviaans-kloof	200 m	Impure sand-stones.
	Bokkeveld	Gydo		Shale and siltstone

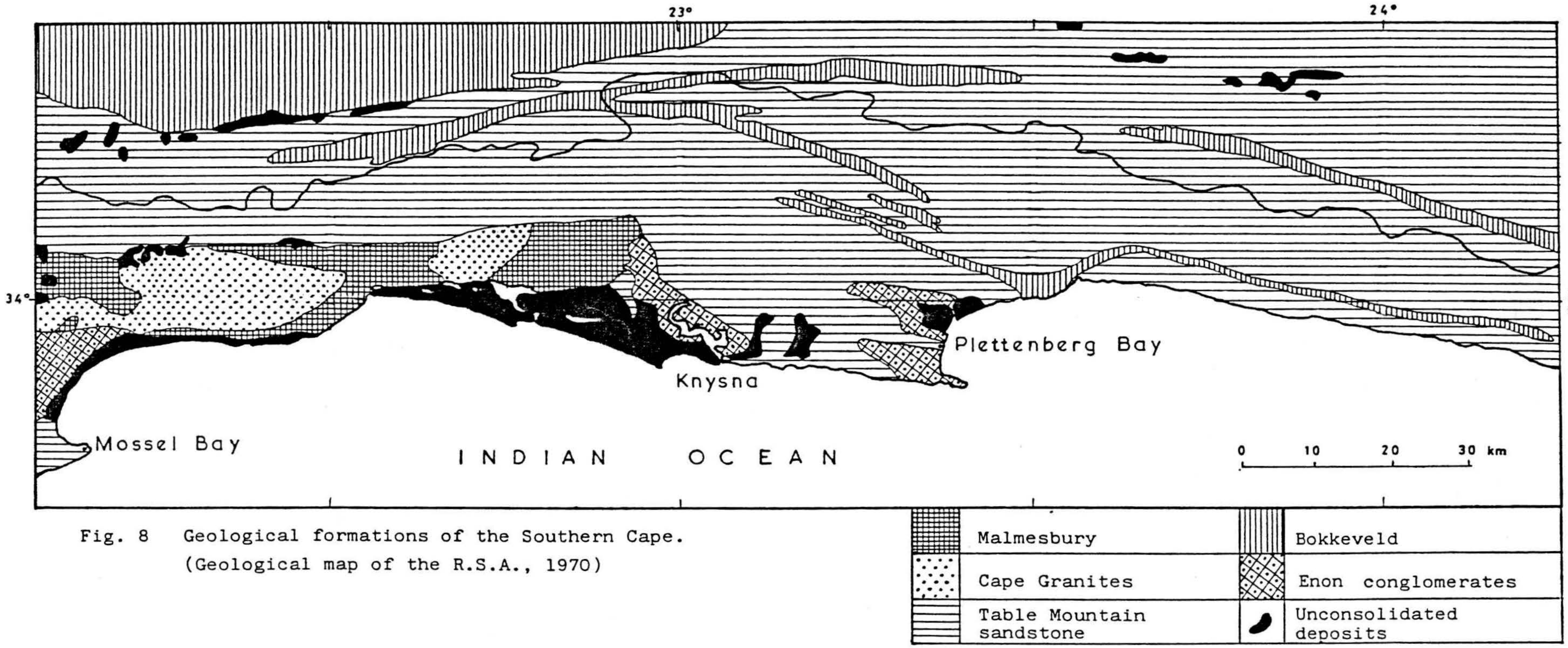

Fig. 8 Geological formations of the Southern Cape.
(Geological map of the R.S.A., 1970)

on the fault contact lines against the Table Mountain Sandstone and reach thicknesses of up to 200 m near Knysna (Tyson, 1971, p. 5; Toerien, 1979, p. 8). These deposits consist of pebbles and rounded boulders.

Unconsolidated deposits of aeolian sand, dune sand, alluvial and marine terraces occur mainly along the coast from Plettenberg Bay to Mossel Bay, with the coastal dunes being the youngest deposits (Toerien, 1979, p. 9). The geological formations in Fig. 8 are shown to transgress across the boundary of the study area in the north. This is done to facilitate an understanding for the location of the mountain range concerned.

Reference to the impact of geological formations on indigenous forest cover is generally scarce in scientific literature. Phillips (1931, p. 17) mentions that this impact is generally underrated. High climax forest is associated with all beds of the Southern Cape except the Enon beds and more recent unconsolidated sand deposits (Laughton, 1937, p. 38). The moister forest type in the Knysna region is also generally associated with Table Mountain Sandstone and the beds of the Kaaimans Group, while the drier forest type is associated with Bokkeveld shales (Phillips, 1931, p. 17).

According to Van Daalen (1981, p. 16), forests occur on all soil types except those derived from Enon conglomerates and granites. The forest vegetation is only significantly influenced by the underlying rock if the latter is close to the soil surface, thereby impeding root penetration (Van Daalen, 1980, p. 104). With regard to soil formation Grey (1981) states that "It has been established that the hard rock geology is a poor guide to soil type."

It appears that forest distribution in South Africa as a whole is strongly associated with the occurrence of sandstones and particularly an admixture of shales, sandstones and igneous rocks, examples being:

(a) The Karkloof forest (area = approximately 8 000 ha) in Natal, which is associated with sandstones and shales of the Beaufort Group in association with dolerite (Taylor, 1961, p. 124);

(b) the Nxamalala forest (area = approximately 610 ha according to Scriba, 1971, p. 3) in Natal on sandstones and shales of the Ecca Group also in association with dolerite (Taylor, 1963, p. 30);

(c) the Mariepskop forests in the Eastern Transvaal associated with sandstones sand-shales and quartzites of the Black-reef formation, which overlie granite (Van der Schijff and Schoonraad, 1971, p. 464);

(d) the Ngome forest (area = 2 636 ha) which occurs on Middle Ecca Sandstone intruded by dolerite (Bainbridge, 1975).

3.2 Physiography and Geomorphology

The principal and dominating feature affecting the soil, climate and vegetation of the Southern Cape, is the Outeniqua mountain range and its foothills. This range divides the moist, coastal lowlands from the dry Karoo hinterland. Largely as a result of the highly contorted folding of the Table Mountain Sandstone and the subsequent erosion cycle, the Southern Cape can be divided into four distinct physiographic regions (Tyson, 1971, pp. 7 - 8; Von Breitenbach, 1974, p. 17):

(a) The sandy, coastal lowlands, termed "embayments" by Tyson (1971, p. 8) and "littoral" by Von Breitenbach (1968, p. 70);

(b) the coastal platform - Von Breitenbach (1968, pp. 70 - 71) actually distinguishes between a lower and an upper plateau in this regard - which occurs at an elevation between 150 - 300 m (Geldenhuys, 1981);

(c) the foothill zone, a fairly narrow region between the coastal platform and the mountain at an altitude between 350 - 550 m, and

(d) the mountains themselves.

A common feature in all four regions is the rugged nature of the terrain (Tyson, 1971, pp. 7 - 9), resultant from the frequently deep north to south orientated river incisions and the general cleavage dip in a S to SW direction of between 60° to 80° (Grey, 1981), the latter particularly noticeable west of Wilderness.

Tyson, (1971, pp. 9 - 11) associates the geomorphological history of the coastal platform with different sea levels, coastal emergence and submergence. It appears that the ocean level has fluctuated from 180 - 240 m above the present position before the Miocene 22,5 m.y. ago (Truswell, 1977, p. 189) to 55 m below the present level during the Miocene, thereby establishing the coastal platform with its deeply incised river estuaries (Van Daalen, 1980, pp. 96 - 98). The present coastal littoral zone is associated with the Pleistocene 1,8 m.y. ago (Truswell, 1977, p. 189), where the once again receding sea levels has resulted in a series of dune and sand ridges, behind which the Lakes region is presently situated (Van Daalen, 1980, p. 97; Tyson, 1971, p. 11).

The indigenous forests appear closely associated with the coastal platform and foothill zone, provided the soil and climate are suitable (Tyson, 1971, p. 14; Von Breitenbach, 1968, p. 96).

Literature on the effect of topographical features on the forest location pattern is rather scarce. It was for this reason that nine transects were drawn across the study area from east to West along meridian lines at approximately ten minute intervals (Fig. 9). It was only at both extremeties that intervals exceded ten minute intervals. In order to emphasise topography more strongly, the vertical scale was exaggerated by five (Monkhouse and Wilkinson, 1961, p. 69). On each transect the forest cover has been indicated by horizontal lines drawn to scale. The general trend tends to be an increase in forest cover on moderately steep gradients, with a steady decrease with distance from the coast-line inland. Forest cover is evidently highest on the "Diepwalle" transect (see Fig. 1) and a shift towards the foothills and mountains is noticeable from this forest heartland area, particularly westward thereform.

3.3 Soils

Relatively little is known about the soils which occur in the wetter forestry areas of South Africa (Grey, 1982, p. 95), and, although the Saasveld Forestry Research Station has completed preliminary soil surveys, the comment can apply to the Southern Cape as well.

Laughton (1937, pp. 39 - 42) describes the forest soils of the Southern Cape according to the parent

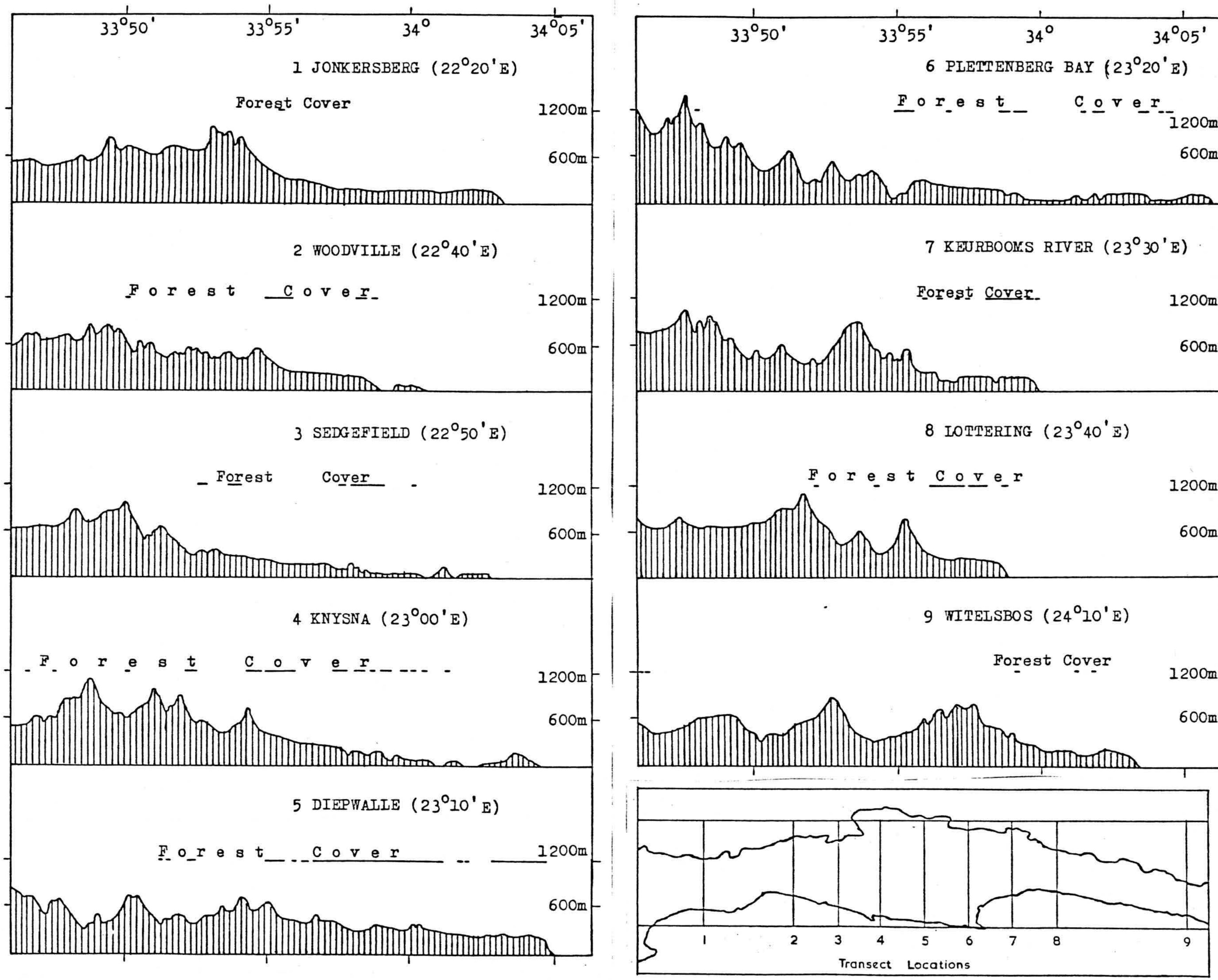

Fig. 9 Nine meridian sections in the Southern Cape study area.
(Source: S.A. 1 : 250 000 topo sheets 3322/3324).
Vertical scale 5 x horizontal.

rock they are found on. Von Breitenbach (1968, p. 92) classifies soils as primarily products of climate and vegetation and less dependent on their parent rock formation with increase in their development. Wellington (1955, p. 22) refers to valley soils in this regard and states that the influence of parent rock "... is obliterated by soil forming processes."

The soils of the Southern Cape can broadly be classified into three types according to Tyson (1971, p. 13 - 14), namely:

(a) Youthful, azonal soils, which are found as shallow, undeveloped layers along the steeper TMS slopes, but also include unconsolidated sand dunes along the coast and marsh soils within the lakes region. The mountain soils are strongly correlated with their parent material while the deeper coastal sands are calcareous (Kruger, 1979, p. 25);

(b) Brown and Grey soils, which are associated with the foothill zone and specifically restricted to slopes less than 12° (Tyson, 1971, p. 13). Von Breitenbach (1974, p. 17) refers to these simply as foothill sandy-loam soils;

(c) Lateritic Palaeosols, which occur mainly on the coastal platform and are frequently associated with poorly-drained parent material.

Heydorn and Tinley (1980, p. 13) also classify local soils into three types, namely weakly developed shallow soils of arid regions along parts of the plateau, littoral sands in the Lake's region and lithosols for the mountain and foothill zone.

Von Breitenbach (1968, p. 77) classifies the Southern Cape soils texturally into sand, sandy loam, loam and clay soils, the sand occurring on the littoral, the sandy loam along the foothills, the loams on the plateau, with the latter plateau soils also featuring a clay sub-layer (Von Breitenbach, 1974, p. 17).

Von Christen (1964, p. 8) makes a general distinction between residual soil, which he attributes to the mountains, and, what he terms "drift" soils on the plateau.

The above discussion briefly reflects the "soils classification" of the past. Presently, and this applies to the past four to five years, the Site Research Section of Saasveld Forest Research and the Soil and Irrigation Research Institute, Pretoria, are active reclassifying local soils. Grey (1981) describes the present problem aptly: "The coastal zone south of the Outeniqa mountains is notorious for its very complex soils." In one traverse he mentions eight soil forms and two profiles which could not be satisfactorily accommodated according to the S.A. Binomial Soil Classification System (MacVicar, De Villiers, Loxton, Verster, Lamprechts, Merryweather, Le Roux, Van Rooyen and Harmse, 1977).

Fig. 10 represents an attempt to provide a generalised and somewhat simplified picture of the complex soil types. Although the soil forms within each soil type are not uniform, typical soil forms are shown as examples of each type. Fig. 6 is adapted from unpublished data compiled by the Soil and Irrigation Research Institute (S.I.R.I., 1983).

The six soil types are briefly described below, with brief comment as to forest coverages. The latter was determined by comparing Fig. 6 and Fig. 10.

(a) Regic Sands

These hardly need explanation as they consist of deep uniform sands of medium texture, frequently calcareous. Being unconsolidated they do not feature large indigenous forest areas. The forest flanking Groenvlei is an exception. Typical soil form: Fernwood (S.I.R.I., 1983).

(b) Duplex Soils

These are typical soils of the plateau region, with a relatively permeable top soil which overlies a slowly permeable diagnostic horizon (Mac Vicar et al, 1977, p. 126, Van Daalen, 1981, p. 16), hence the term "duplex". The Sub-soil is normally gleyed. This soil type does not as a rule feature consolidated climax forest except in portions of the Tsitsikamma, mainly because the soils are badly drained. Typical soil form: Estcourt, often podsolised in the wetter areas (Grey, 1981).

(c) Lithosols and Lithocutanic Soils

These soils occur on younger landscapes normally on the slopes of the foothills, the steeper river incisions and the steeper coast-lines. Soils usually feature a rocky base, parent material in fact often exposed. Representive soil forms are Mispah and Glenrosa (S.I.R.I., 1983). These soils are well-forested, particularly in higher rainfall areas, where they are better drained than the duplex soils.

(d) Podsols

Podsols are characterised by removal of aluminium and iron oxides (sesquioxides) and organic matter from the A horizon, which are deposited as ferri-humics in the B horizon (MacVicar et al, 1977, p. 133 and 135), along the foothills of both the Outeniqua range and below the upper plateau. The soils occur mainly in higher rainfall areas, and are locally associated with recent colluvation of TMS material as well as aeolian sand drifts. The Lamotte form is an outstanding example. These soils together with the Lithocutanic (Lithosol) group feature the highest natural forest coverage as well as pine plantation cover. One has to keep in mind, though, that there is not a very "clear nor simple relationship between soil morphology and tree growth" (Grey, 1981).

(e) Red Apedal Soils

These are well drained soils which dominate along a narrow strip from Wilderness to Herolds Bay, although apedal soils occur in a less dominating form elsewhere as well. The Hutton (red) and Clovelly (yellow-brown) forms are the most common. Being well-drained they only feature light scrub forest, usually of the dry type.

(f) Unconsolidated Soils and Exposed Rock

Fig. 10 shows this broad soil type to cover almost 40% of the study area. It consists to a large extent of exposed TMS rock, according to S.I.R.I. (1983), between 60% and 80%. This is confirmed by a separate survey, where a 56% rock exposure area was determined for an Outeniqua mountain area studied north-east of George. Aerial photographs (Flight 499/1966) were used for an area that had been traversed by fire. The remaining soil covered area, mainly located below steeper slopes, has undergone active "creep-colluviation" (Grey, 1981). Both Grey (1981) and S.I.R.I. (1983) refer to the Oakleaf form as dominating in this soil type.

These steeper mountain soils are covered by fynbos, with forests only occurring in the protected valleys over a very limited area. The soils are acid and are characterised by accumulation of organic material, hence their dark colour and the fact that rivers eminating from this source belong to the so-called "black"-water system (Du Toit, 1926, p. 185; Rogers, 1905, p. 118).

With reference to soil chemistry, Sim (1907, p. 40) mentions that the physical soil properties are more important than the chemical. Von Christen (1964, p. 8) states that "All soils of the constant area are insufficiently supplied with nutrients", this being mainly due to the siliceous parent material of the dominant Table Mountain Sandstone. A marked deficiency in phosphorus has been noted (Grey, 1982, p. 97). The pH of the mountain, foothill and moister plateau soil, range between five and six and are therefore very acid (Tyson, 1971, p. 13). For the period 1980 to 1983 twenty-two soil samples of A-horizons were collected in the vicinity of Saasveld, eleven each from indigenous forest and adjoining pine plantation. These were analysed for their phosphorus content and their pH-rating. Phosphorus levels were very low in both localities, averaging 6,0 ppm for indigenous forest and a low 3,9 ppm for pine.

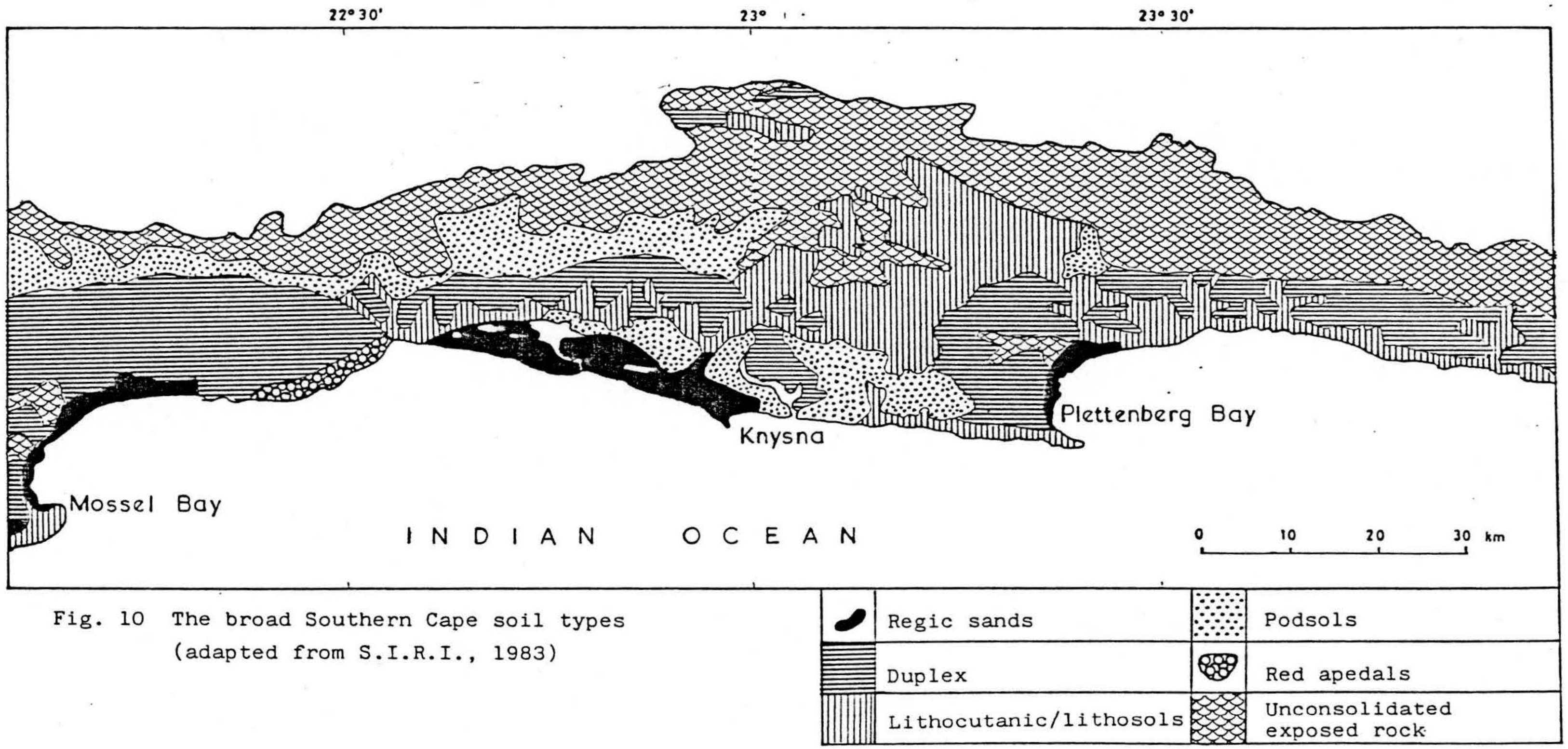

Fig. 10 The broad Southern Cape soil types (adapted from S.I.R.I., 1983)

The pH-tests also showed meaningful differences, the indigenous forests averaging 4,53 (range 4,10 to 4,97) while the pine plantation alongside average 4,01 (range 3,62 to 4,56). Soils eminating from and residual on Bokkeveld shale are regarded as fairly fertile, though often leached of soluble ingredients (Wellington, 1955, p. 22). Granitic soils, though frequently highly leached, also have a high concentration of nutrients (Kruger, 1979, p. 27). It would therefore appear that from a nutritional and textual point of view, an admixture of Bokkeveld shales and possibly granitic soils should prove to provide the best soil base for indigenous forest development (Wellington, 1955, p. 22).

3.4 Climate

The climate of the Southern Cape is largely dependent on atmospheric and oceanic circulation systems (Wellington, 1955, p. 128). Wellington equates a direct relationship between the oceanic circulation around the Southern African coast with the atmospheric circulatory system, i.e. anti-cyclonic movement around the oceanic high pressure systems east and west of the subcontinent, which results in the warm Agulhas current flowing to increasing latitudes along the east coast, while the colder Benguella current flows towards the tropics along the west coast. The moderate Southern Cape climate can be partially ascribed to the temperatures of the warm Agulhas current. The mean oceanic temperatures decline from 21,8°C at Durban to 16,8°C at Knysna, which is however still well above Cape Town's 12,8°C in the Benguella drift. The mean Agulhas drift reaches a maximum strength of 60 km per day (maximum of 190 km/day) during April, with its weakest in July at 40 km/day (adapted from Wellington, 1955, p. 130).

As far as atmospheric circulation is concerned, the climate at any one place is influenced by two physical processes, planetary atmospheric movement and local modification thereof. The weather of the Southern Cape is particularly influenced by a succession of east-moving subtropical low-pressure cyclones interacting with subtropical high pressure anti-cyclones located over the oceans (Heydorn and Tinley, 1980, p. 20). The anti-cyclonic air masses are associated with dry subsiding air masses of the subtropics, while the low-pressure cyclones are equated with moist, ascending air masses.

The Outeniqua mountains have a profound effect on the local weather pattern, by acting as a barrier to the inland penetration of shallow weather systems and by invoking typical orographic precipitation (Tyson, 1971, p. 13).

The broad Southern Cape climatic pattern has been classified by Schulze and McGee (1978, p. 39) as a Cfb according to the Köppen classification, i.e. C = the local forest are thereby associated with a warm, temperate climate (coldest months between -3°C to 18°C); f = sufficient precipitation during all months and b = warmest month below 22°C, with at least four months above 10°C. According to the Holdridge Life Zone classification which stresses the major vegetation delimitations and is based on different moisture regimes along latitudinal and altitudinal gradients, the Southern Cape forests falls into the 2 h classification, i.e. Subtropical, lower montane, humid-moist forest.

3.4.1 Precipitation

There exists a direct relationship between living plant biomass and available water. It can therefore be deduced that precipitation is a key to forest vegetation. Schulze and McGee (1978, p. 29) mention water availability as the most important climatic parameter. Wellington (1955, p. 263) however also stresses the opposite as important to the South African climatic picture, namely drought, describing it as the failure of natural vegetation to support a population of stock which one has reason to expect in a particular area.

The Southern Cape lies in the constant rainfall area. Wellington (1955, pp. 201 - 213), discusses various weather types which favour precipitation in this area. During the summer months the Southern Cape receives most of its rain only when the summer low pressure system, normally located in northern Botswana, shifts south (Weather Type D), or when a low pressure trough extends from Botswana far enough South to feed in moist air (Weather Type C). The latter rainfall, although very rare, is associated with thunderstorms. Winter rainfall in the Southern Cape is frequently associated with a coastal Low which moves from west to east together with an inland High located over the eastern subcontinent (Weather Type F). This is the normal weather pattern following berg winds. However, summer and winter rainfall is on the whole lower than spring and autumn rainfall (Fig. 11). Spring (September to November) and Autumn (March) rainfall is usually induced by cold fronts, which originate in the South Atlantic and move across the southern coast-line in an easterly to north-easterly direction (Tyson, 1971, pp. 11 - 12).

The rainfall is normally soft drizzle and torrential downpours are rare, so are thunderstorms and hail. The rainfall range within the study area is between 400 mm on the western plains to about 1 200 mm per annum in the forest heartland north of Knysna as well as the Tsitsikamma coastal plateau (Von Breitenbach, 1968, p. 84, Fig. 13).

Fig. 13 is an Annual Rainfall map of the Southern Cape which was specially compiled for purposes of this study. It is based on rainfall data from 69 recording stations, which are all indicated on Fig. 13. Of these 53 stations feature data exceeding 30 years, 14 exceed 20 recording years and only two stations feature data below 20 years (Department of Transport, 1965; 1970).

The simple isohyets drawn at 100 mm intervals, were determined by interpolation construction, meaning that altitude was altogether disregarded. Von Breitenbach (1968, p. 85) has observed in this regard that there is a gradual reduction in the amount of rainfall with increase in altitude within the Outeniqua mountains, as well as with distance from the coast. Unfortunately the higher mountains feature few to no recording stations to prove such reduction, but existing published annual rainfall maps tended to overestimate precipitation by an average 150 mm in eight marginal recording stations on either side of the Outeniqua range.

Von Breitenbach (1968, p.85) and Phillips (1931, p. 47) describe the Southern Cape rainfall pattern as overlapping or as a merger between winter and summer rainfall pattern. It was therefore

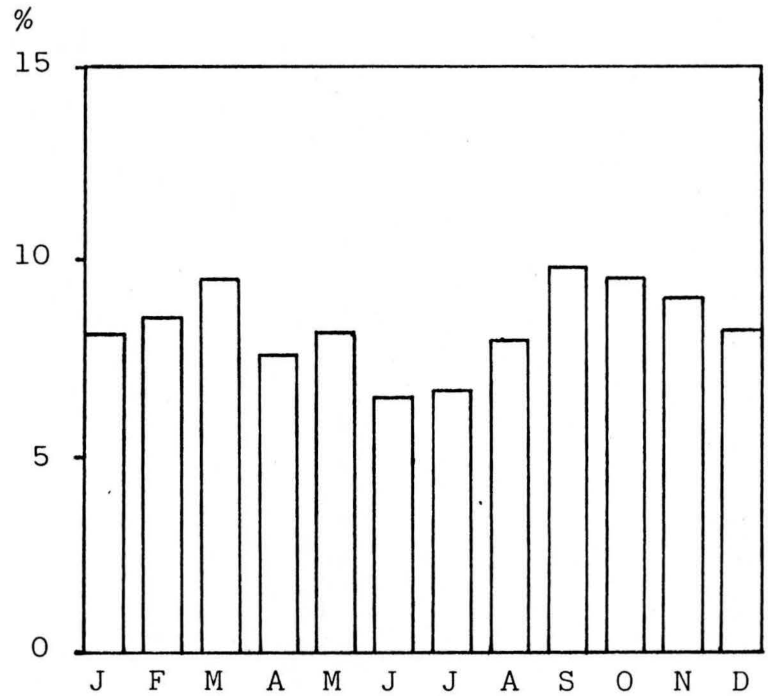

Fig. 11 Average monthly rainfall of Southern Cape, expressed as percentage of average annual rainfall (data from Department of Transport, 1960)

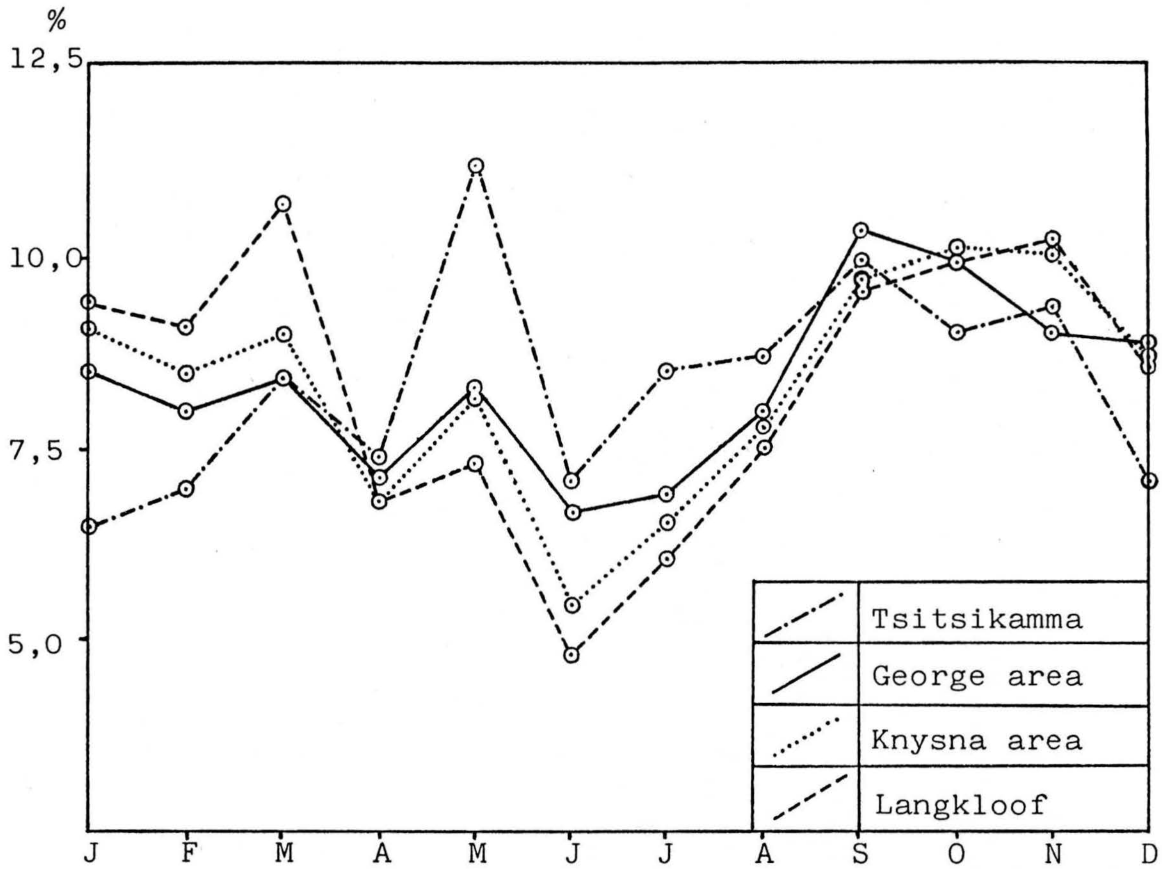

Fig. 12 Variation in monthly rainfall of Southern Cape expressed as percentage of annual rainfall. (Data from Department of Transport, 1965).

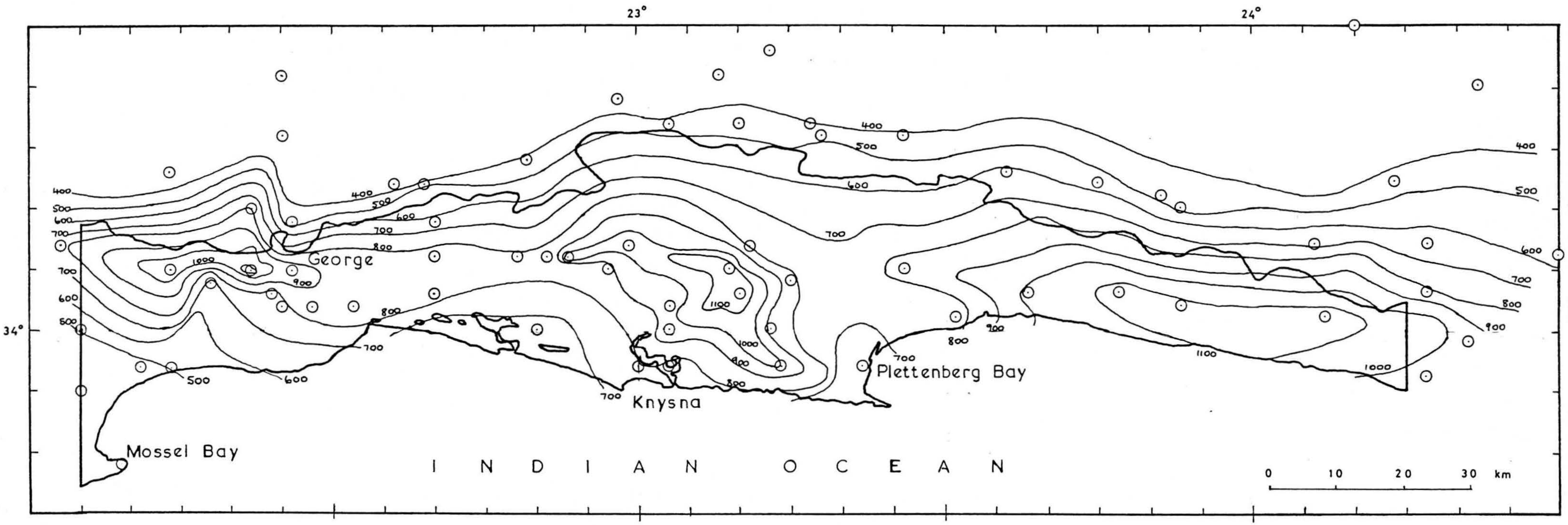

Fig. 13 Mean annual rainfall (mm) of the Southern Cape, based on data from 69 recording stations.
(Data from Department of Transport, 1965).

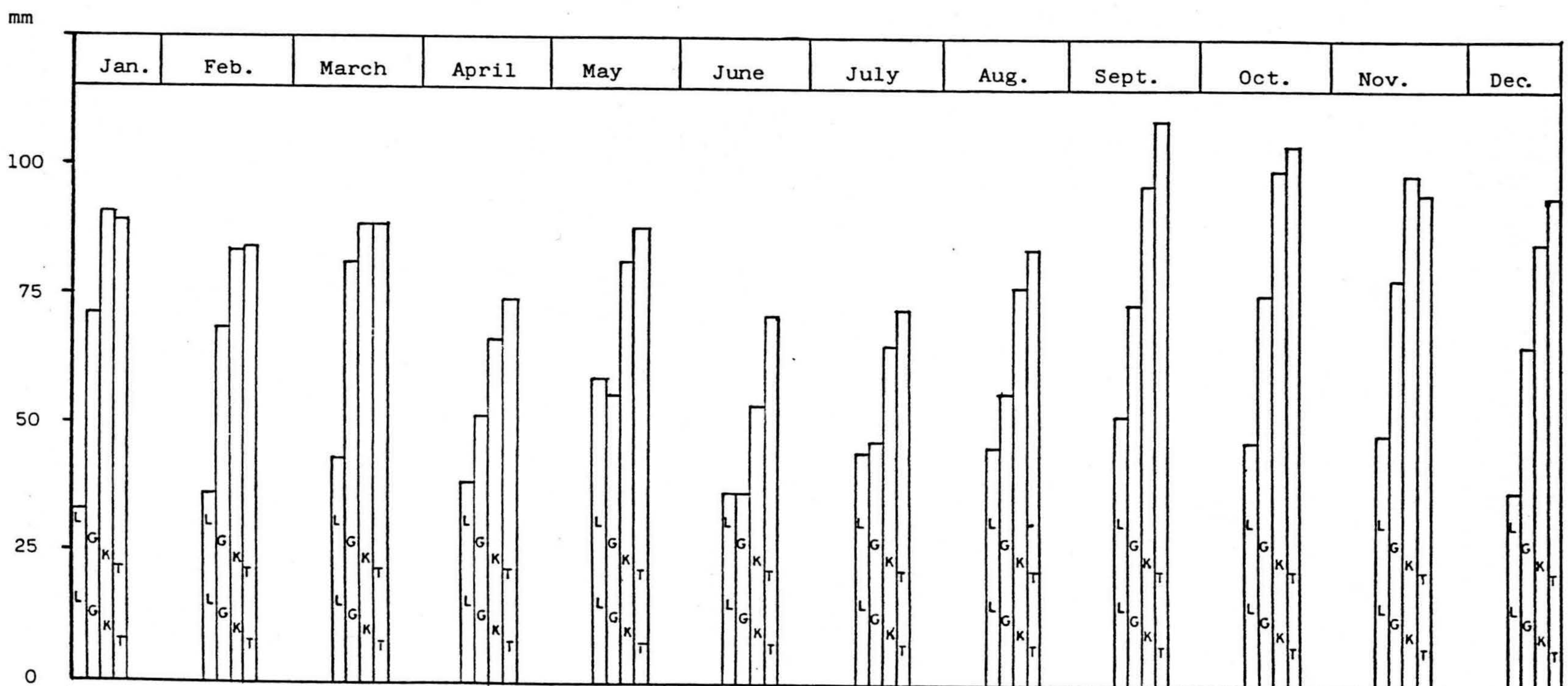

Fig. 14 Mean monthly rainfall variation patterns in the Southern Cape.
(Data from Department of Transport, 1965).

L	Langkloof
G	George
K	Knysna
T	Tsitsikamma

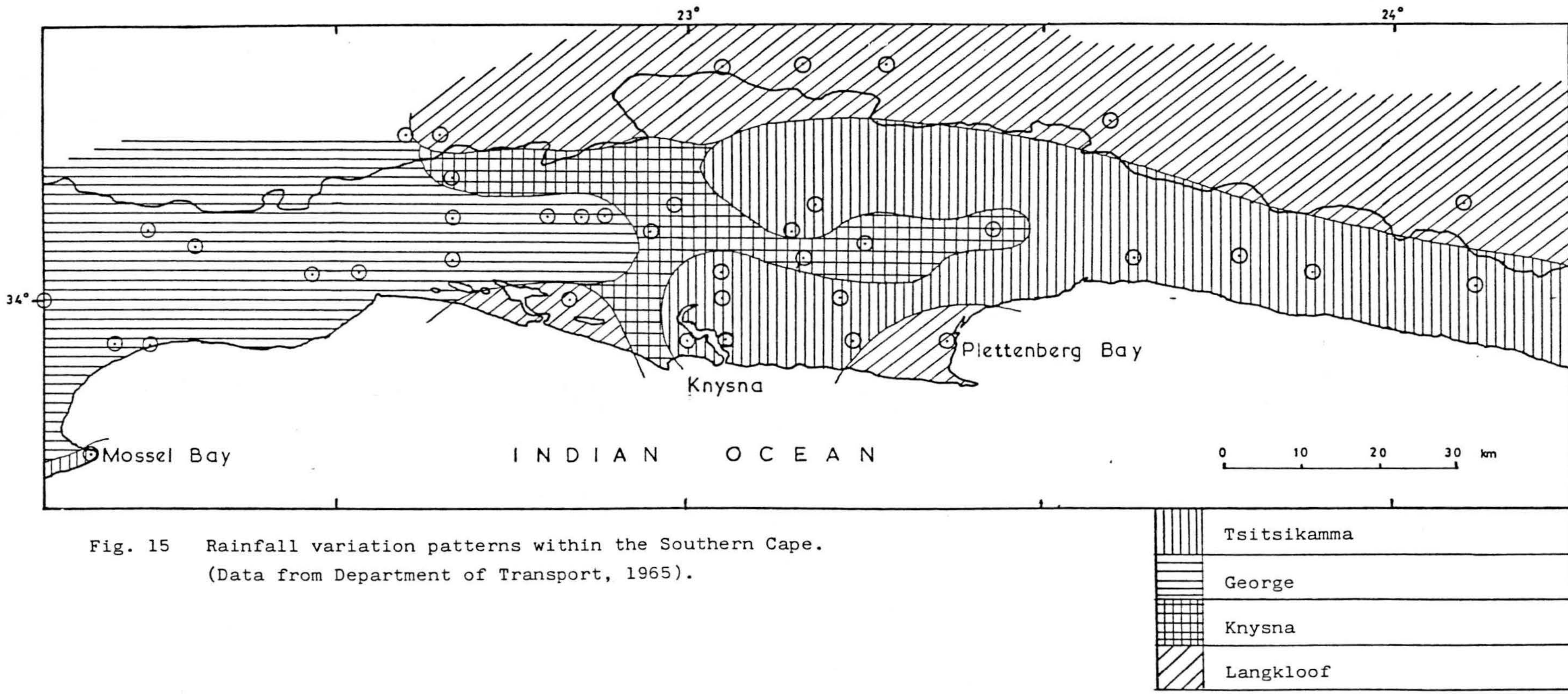

Fig. 15 Rainfall variation patterns within the Southern Cape.
(Data from Department of Transport, 1965).

decided to investigate this aspect more closely. Forty-five recording stations, each featuring more than 30 years of rainfall recording, were selected for this purpose (Fig. 15). The sequence of the four highest respective average rainfall months were thereupon determined and recorded. Four fairly distinctive patterns were recognisable, and were deliminated as follows:

(a) The Tsitsikamma (Fig. 15) with a more dominant spring rainfall pattern, the wettest months being September and October (Fig. 14). Rainfall statistics of seven stations were used to represent this Spring-rainfall trend in Fig. 12 and 14. These are Condordia, Kaffirkop, Lottering, Buffelsnek, Bloukrans, Stormsriver and Witelsbos (Department of Transport, 1965: 1970). The mean annual rainfall for this group is 1 050 mm, the highest of the four. Fig. 14 actually shows the monthly rainfall in millimetres (mean 87,9 mm) and accentuates the abovementioned average spring rainfall. Only September and October and to a lesser extent November and December rainfall are above the monthly mean of this group, all other months falling on or below this mean. The month of May features a monthly average figure as well (refer to the Langkloof rainfall trend);

(b) The George Area (Fig. 15), represented in Fig. 12 and Fig. 14 by eight stations, namely Kwepertuin, Kleinfontein, Saasveld, Geelhoutboom, Groot Brak, George, Bergplaats and Farleigh (Department of Transport, 1965; 1970), with a more distinctive spring to early autumn rainfall. Fig. 14 shows the months from September through to March to be above the average of 63,5 mm, the late-autumn to winter months being relatively dry. The mean annual rainfall of these eight stations is 760 mm;

(c) The Langkloof (Fig. 15), represented by Avontuur, De Hoop, Kleinrivier en Wolwekraal on the northern side of the Outeniqua crest, but also Plettenberg Bay and Ruigtevlei (Department of Transport, 1965; 1970). These rather dry areas with an average annual rainfall of 520 mm and a monthly average of 43,5 mm (Fig. 14), reveal distinct early-winter and to a lesser extent early-spring rainfall dominance, the month of May featuring particularly prominently (Fig. 14);

(d) The Knysna Area (Fig. 15), represented in the more detailed analysis (Fig. 12 and 14) by Millwood, Kransbos, Diepwalle and Keurbooms (Department of Transport, 1965; 1970). This region receives a mean annual rainfall close to 1 000 mm with a monthly average of 82,3 mm (Fig. 14). This area, detailed on Fig. 11, appears to be a merger for the previous three rainfall trends because it features all three trends. It features above average spring rainfall (Fig. 14) with September to November featuring equally prominently, the summer to early-autumn months, namely December to March, are close to average, and the month of May - well below average in the George area, features average monthly rainfall.

Fig. 12 provides the same information as Fig. 14 with the exception that the mean monthly precipitation for each of the four patterns is expressed as a percentage of its mean annual precipitation. This facilitates better comparison possibilities, e.g. Fig. 12 shows that the months of April (low rainfall) and September reveal very similar trends in all four areas, while January, February and the winter months reveal widely divergent trends.

Tyson (1971, p. 12) refers to rainfall fluctuations evident in three, ten and 30 year cycles in the George-Knysna area. Rainfall phases or cycles of above to below average rainfall periodicities have already been investigated by Schumann (1934), Wicht (1949) and more recently by Tyson and Dyer of the University of the Witwatersrand (Oosthuizen, 1977). Wellington (1955, pp. 269 - 272) describes these secular variations in rainfall as well. Scriba (1971, p. 6) mentions the occurrence of fairly regular and distinctive rainfall phases in five recording stations in the Natal Midlands. The annual rainfall data for George for the period 1878 to 1982 (Sawyer, 1983) was subjected to analysis and comparisons between the George and Natal Midland centres appear in Table 4.

The 1911/12, 1916/17, 1943/44 and 1958/59 phase changes appear rather significant, although most Natal Midland centres only have a phase length reliability (Wellington, 1955, p. 270) of about 73% (Scriba, 1971, p. 7). Swartkop Plantation and Elandskop though, have phase length reliabilities in excess of 85%. What is far more interesting though, is why certain phases are altogether

TABLE 4 COMPARISONS OF DRY AND WET RAINFALL PHASES BETWEEN GEORGE AND FIVE NATAL MIDLAND CENTRES (Scriba, 1971; Sawyer, 1983)

PHASE TYPE	YEARS OF PHASE	NATAL MIDLANDS					CAPE	COMMENT AVAILABLE DATA (years)
		Swart-kop (1911)	Pieter-maritz-burg (1903)	Dalton (1901)	Cedara (1914)	Elands-kop (1930)	George (1878)	
		1884/85					***	
Wet							6/3	
	1893/94						***	
Dry			-	-			1/6	
	1904/05		***	***			1901	
Wet		-	5/2	6/1			10/2	
	1911/12	***	***	***			***	
Dry		1/4	1/4	2/3			8/9	No proper phase in George
	1916/17	***	***	***	***			
Wet		7/2	3/2	6/3	5/3			
	1925/36	***	1921	***	1924		1927	
Dry		3/7	3/9	1/7	3/10	-	11/5	
	1933/34	1935	***	***	1937	***		Wet-George
Wet		6/2	6/4	7/3	7/3	7/3		
	1943/44	***	***	***	1947	***	***	
Dry		1/8	1/9	3/9	1/7	1/8	0/8	
	1952/53	***	***	1955	1955	***	1951	
Wet		5/1	10/1	4/0	3/0	6/1	12/4	
	1958/59	***		***	***	***		Wet-George
Dry		3/7		0/4	3/4	2/5		Wet-PMBurg
	1965/66	1968	1964	1963	***	***	1967	
Wet		8/2	-	-	-	-	1/7	Dry-George
	1978/79	***					1975	
Dry		0/3					5/2	Wet-George
Average Phase Length (yrs)		8,4	8,6	7,4	8,2	8,3	11,1	

NOTE: (1) *** denotes correlation with phase change, otherwise the year of change is indicated;

(2) the ratios of years are always given in the sequence Wet/Dry;

(3) "Wet" means above-average, and "Dry" below-average rainfall.

lacking in some centres. It is not the purpose with this study to venture into this aspect any further, except to refer to the variation in rainfall patterns (Fig. 15), which could possibly provide more clarity on the incidence of rainfall phases. With regard to the Natal Midlands situation, it is obvious that localities like Swartkop and Cedara, which lie on opposite slopes of one mountain range or spur, will benefit differently from orographic and convectional rainfall at any given time.

When comparing Fig. 15 with the forest distribution map, Fig. 6, the forest location pattern appears closely associated with the precipitation pattern, the higher the rainfall the larger the forest cover.

3.4.2 Temperature

Temperature in itself is possibly not a major criterion explaining plant region diversity, yet its indirect effect on evapotranspiration must be regarded as very important, particularly as far as plant variation in a particular locality is concerned (Schulze and McGee, 1978, p. 25). Temperature data for the Southern Cape is sparse (Phillips, 1931, p. 39). This still applies today. Apart from data provided by the Weather Bureau from three stations Mossel Bay, George and Stormsriver (Department of Transport, 1970; Fig. 16), there is limited published representive temperature data available. laughton (1937, p. 45) provides accurate temperature data for Diepwalle north of Knysna for the period 1923 - 1934. Phillips (1931, pp. 55 - 69) provides detailed temperature measurements for Belvidere, Kaffirkop and Diepwalle for the years 1923 - 1925 under a variety of conditions, viz. air temperatures measured at three different altitudes (3 m, 360 m and 530 m: Table 5), air temperatures under forest cover, on northern and southern aspects as well as various soil temperature measurements.

Table 5 shows that temperature variations are, in Phillips' (1931, p. 39) own words, to be regarded "... as the most equable in Southern Africa." The normal effect of altitude on air temperature is a drop of about 0,6°C for each 100 m rise in altitude (Spurr, 1964, p. 41). In this case it works out to a drop of 0,3°C for each 100 m altitude. Points of significance in Phillips' temperature statistics are a general drop of about 6°C noted between the maximum daily temperatures of exposed areas to temperatures in forest covered areas, and the effect that aspect has on daily maximum temperatures (Phillips, 1931, pp. 40 - 63). In this latter regard Phillips measured temperatures at 15 cm, at 6 m and at 12 m above ground-level and found the average temperature difference between northern and southern aspects in these categories on a 15° slope to be 3°C, 1,2°C and 1,3°C respectively.

Fig. 16 shows the average monthly temperatures of Mossel Bay (Cape St. Blaize), George and Stormsriver for the year 1970. The respective mean annual temperatures are 17,1°C, 15,7°C and 16,3°C. This data more or less confirms Spurr's findings, representing an average drop of 1°C in 148 m between George and Mossel Bay. The highest temperature recorded in George is 41,3°C (January) and the lowest 1,3°C (July), (Department of Transport, 1954). Frost is therefore very rare. Berg wind conditions, caused by a strong sub-continental anti-cyclone and a low pressure system moving from West to East south of the Cape, causes very warm weather conditions (Heydorn and Tinley, 1980), while cold spells usually occur when strongly developed cold fronts are

TABLE 5 AVERAGE MONTHLY TEMPERATURES OF THE KNYSNA AREA IN 1923
(Phillips, 1931, pp. 56 - 59)

LOCALITY	ALTITUDE (m)	REPRESEN-TATION	MONTHS OF THE YEAR												AVERAGE
			J	F	M	A	M	J	J	A	S	O	N	D	
Belvidere	3	Coast	19,7	20,6	20,3	17,5	14,1	13,4	12,8	13,4	14,5	17,0	18,4	19,5	16,8
Kaffirkop	360	Forest Margin	18,5	18,3	19,1	16,8	14,4	13,8	13,2	14,6	14,2	15,6	16,3	18,3	16,1
Diepwalle	530	Forest Margin	18,3	18,3	18,4	15,6	13,0	12,1	11,7	13,2	13,2	15,5	16,1	17,2	15,2

followed by a high pressure anti-cyclone, thereby drawing in cold polar air.

The direct heating of the earth's surface by sun radiation (insolation), alternatively the reflection of such radiation by clouds, is closely related to atmospheric temperature (Wellington, 1955, pp. 226 - 229. Wellington indicates that the Southern Cape is among the few localities which feature a fairly constant and regular sunshine duration of 60% throughout the year. Fig. 17 broadly substantiates this. There appears a close and logical affinity between cloud cover and precipitation, i.e. the autumn (March in particular) and spring months feature a low mean monthly sunshine duration of about 50% in the case of George and Diepwalle (annual rainfall respectively of 873 mm and 1 210 mm). The drier Mossel Bay (rainfall of 419 mm) features a much longer sunshine duration of close to 60% during these periods. The monthly sunshine appearing on Fig. 17 has unfortunately not been recorded at the same time, Diepwalle's data covering the period 1930 - 1939, George's 1950 - 1960 and Mossel Bay's 1941 - 1943.

Solar radiation (insolation) and particularly its impact on local plantgrowth, has not yet been investigated. According to Frank and Lee (1966, p. 1) this important ultimate energy source should be considered in all vegetation research work. Frank and Lee (1966, pp. 28 - 29) devised a Radiation Index (R.I.) based on the simple sin-relationship at different latitudes (from 30° - 50°), for different slopes and aspects for different seasons of the year. This index was used in the analysis of the indigenous forest location pattern, referred to later on.

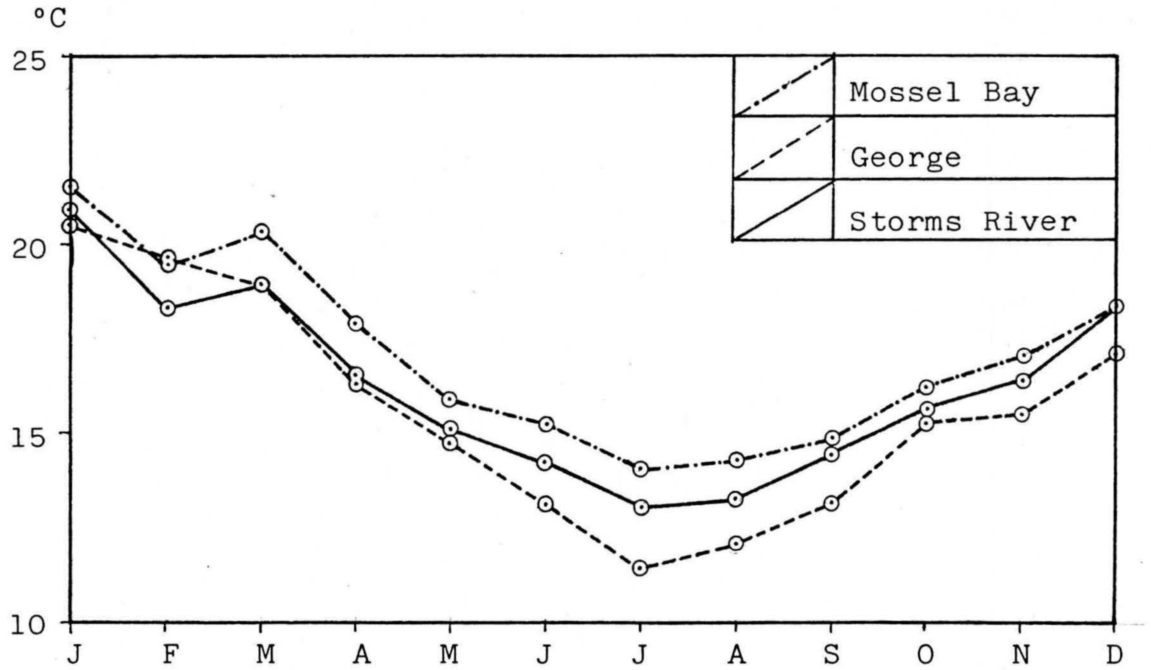

Fig. 16 Average monthly temperatures of three selected centres in the Southern Cape. (Data from Department of Transport, 1970).

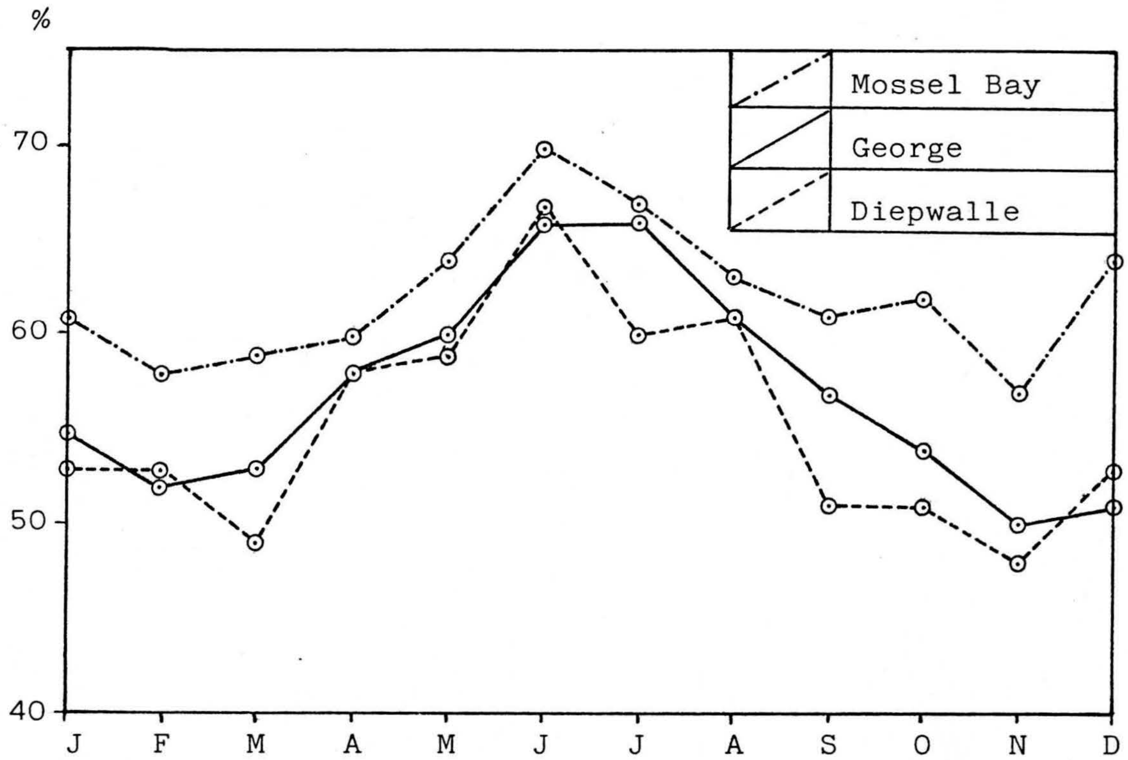

Fig. 17 Percentage montly sunshine duration of three selected centres in the Southern Cape. (Data from Department of Transport, 1970).

3.4.3 Wind

Wind is an important climatic parameter in vegetation research. Caused by the larger cyclonic and anti-cyclonic system of the mid-latitudes, winds of the Southern Cape bring cold and warm air, thereby directly affecting the temperature of a locality; they spread moist and dry air, thereby affecting precipitation, and through their physical impact they cause breakages, distorted growth and can spread or threaten with devastating fires. The causes of cyclone and anti-cyclone pressure systems which affect climate were already discussed in the introductory comment to climate.

The most significant prevailing winds affecting the Southern Cape are the south-westerly rain-bringing winds and the dry, fair-weather south-easterly winds (Laughton, 1937, p. 44; Von Breitenbach, 1968, p. 86). The south-easterlies may occasionally be associated with dense fog. Fig. 18 shows the wind directions of George expressed as a percentage of each month. The "calm" category refers to air movement from 0 to 3,6 km/hour. The autumn months appear calmest of all (Fig. 18 and Table 6). The wind direction N applies from NW to NNE, E applies from NE to ESE, S from SE to SSW and W from SW to WNW. On average 34,2% of the annual pattern is calm weather, 21,5% constitutes winds from a westerly direction, 16,6% from the north, 14,7% from the south and the east wind movement of 13,0% from the east.

Apart from the fair-weather south-easterlies and the moist south-westerlies, the north to north-westerly "berg winds" have a profound influence on the Southern Cape vegetation. Laughton (1937, p. 44) equates all larger fires in the Southern Cape with berg winds and Phillips (1931, p. 52) mentions a positive characteristic, namely rain which "usually follow berg winds."

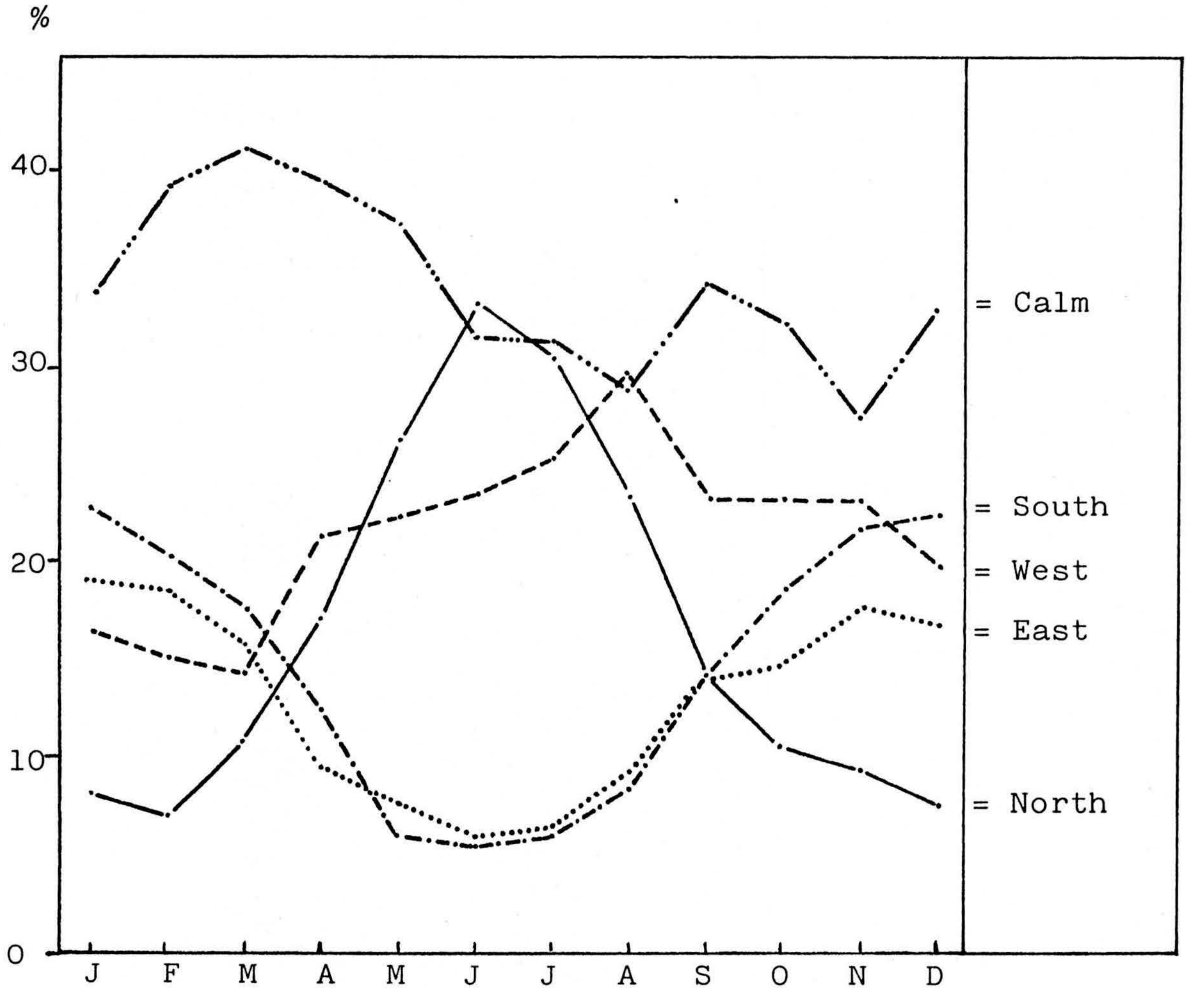

Fig. 18 Monthly percentage wind direction: George 1948 - 1957.
(Data from Department of Transport, 1960).

Fig. 18 shows up some interesting details:

(a) The winter months are overall windy, with northerly (berg winds) and westerly winds dominating; southerly and easterly winds are less frequent (see also Fig. 19). Wind speeds are at their highest during winter from June to August (Table 6);

(b) the summer months are characterised by fairly even south-easterly to south-westerly winds; winds from a northerly direction are less frequent (Fig. 18, 19). Mean wind speeds are also reasonably high from October to January (Table 6);

(c) The equinoxes (March and September) show up very characteristically as "equi" in respect of wind direction (Fig. 18). March shows all wind directions sharing a common 15% frequency, while September is very similar with the exception of westerly winds, the rain bringers.

TABLE 6 AVERAGE PERCENTAGE MONTHLY WIND SPEEDS: GEORGE
(Department of Transport, 1960-b)

MONTH	WIND SPEEDS (in km/hour)					MEAN WIND SPEED
	0 - 3,6 Calm	3,6-14,4	14,4-27	27 - 45	Above 45	
January	33,9	38,6	22,0	5,3	0,2	10,63
February	39,4	36,8	18,5	5,2	0,1	9,76
March	41,2	38,5	16,9	3,3	0,1	8,94
April	39,7	42,0	14,5	3,5	0,3	8,89
May	37,4	40,2	15,7	6,0	0,7	10,02
June	31,7	41,8	17,8	7,7	1,0	11,23
July	31,3	40,4	17,3	9,2	1,8	11,89
August	29,1	41,6	19,6	8,9	0,8	11,88
September	34,1	43,0	16,1	6,3	0,5	10,31
October	32,2	42,0	19,0	6,3	0,5	10,79
November	27,5	42,9	22,2	6,5	0,9	11,70
December	33,1	38,4	22,3	6,0	0,2	10,91
YEAR	34,2	40,5	18,5	6,2	0,6	10,59

NOTE:

The mean wind speed was calculated by multiplying percentage frequency by average wind speed in each category, and dividing the total of each month by 100.

Berg winds have been described by Laughton (1937), Tyson (1964) and more recently by Heydorn and Tinley (1980, p. 21). Laughton recorded details of the frequency of berg winds for a twelve-year period (1923 - 1934). During that period an average 27,7 berg wind periods were recorded per year, 22,8 (or 82,3%) occurring during the winter orientated April to September period. The least number of berg wind periods per year was eighteen during 1929, and the highest recorded was 45 during 1934 (Laughton, 1937, p. 48). Phillips (1931, p. 52) mentions that the George-Knysna area receives between 30 and 40 berg wind periods per annum. The South African west coast appears to experience a slightly higher frequency of about 50 a year (Heydorn and Tinley, 1980, p. 21).

The berg wind is described as "Föhn-like" which often precede winter anti-cyclones (Kruger, 1979, p. 23). It is associated with increases in temperature mainly due to adiabatic heating resulting from descent and compression from the inland coast-wards, the movement of air being caused between an anti-cyclone system towards a cyclone system with the approach of a cold front (Heydorn and Tinley, 1980, p. 21). Temperature during a berg wind "onslaught" may rise by as much as 10°C, but temperatures may drop again by as much as 15°C within hours as winds switch from north to south with the approach of the cold front. Fig. 19 shows how the north-westerly winds, i.e. berg winds, dominate during winter (July). Fig. 19 also shows up the fair-weather south-easterly winds of summer (January), important for attracting tourists to Southern Cape beaches.

3.4.4 Lightning and Fire

Soil, vegetation types and fire occurrence should be viewed as secondary environmental factors, soil

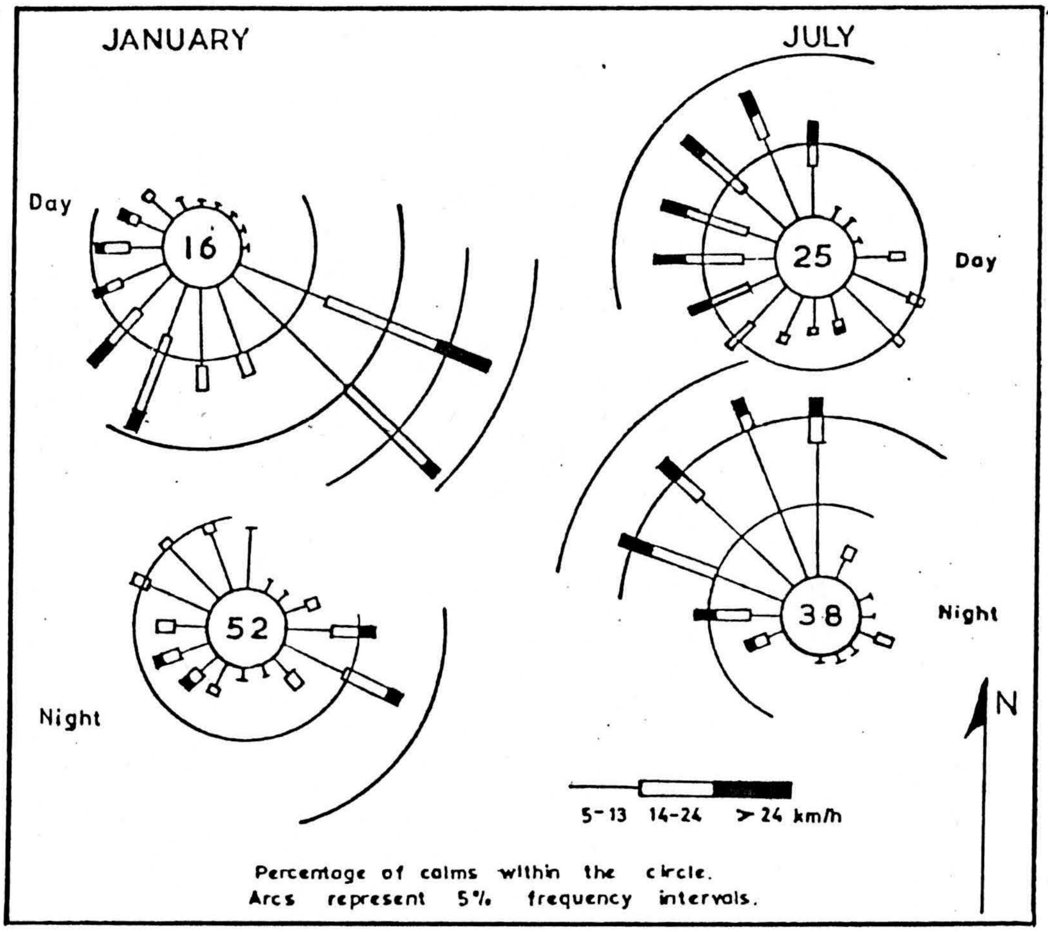

Fig. 19 January and July wind roses for George.
(Van Daalen, 1980, p. 85).

as the product of geology, climate and vegetation; vegetation as the product of geology, soil and climate; and fire as strongly related to climate and vegetation type (Minnich, 1977, p. 449; Philpot, 1977, p. 12; Kemp, 1981, p. 3).

Lighting is a climate criterion which is referred to ever more frequently in vegetation research, although less so in the context of indigenous forest research. Kemp (1981, p. 3) describes fires as "a major environmental factor." The Southern Cape forests are bordered by extensive fynbos vegetation, particularly along its northern perimeters (Fig. 20). Bands (1977, pp. 245 - 251), who equates fynbos vegetation with a typical Mediterranean climate, associates fairly distinct natural fire cycles with this vegetation type; so do Moll, McKenzie and MacLachlan (1977, p. 473).

Mature fynbos can burn virtually any time of the year because of a large accumulation of highly inflammable fuel (Bands, 1977, p. 251). This is unlike grass-dominated systems which generally only burn in winter. Recurring fynbos fires are natural restrictions to forest expansion (Wellington, 1960, p. 84; Moll, 1981, p. 7). Tyson (1971, p. 19) refers to the retreat of forest margins as a result of particularly human-induced fires over a long period of time, and attributes the existing forest location to areas "that cannot burn" because of high rainfall and human inaccessibility. Haggett (1979, p. 172) mentions that there are indications that certain native species have evolved in Mediterranean chaparral as a result of long-term association with fire. This resumé on fires is intended to briefly refer to the significance of natural fires, as opposed to those induced by human activities, within the Southern Cape indigenous forest context.

Natural fires in South Africa are mainly caused by lightning and falling rocks (Kruger, 1979, p. 27). Kemp (1981, p. 14) quotes volcanoes and spontaneous combustion in coal seams as additional fire causes in Australia, although he attributes more than 80% to lightning as cause, even today still in remote areas. That lightning is still nowadays a very significant natural cause of fire is evident from statistics in Table 7. These represent a wide spectrum of localities, including Canada, California and Western Australia.

The high incidence of lightning fires in the Cedarberg, Cape (35,8%) and the Swartberg, Southern Cape (47,6%) is indeed striking. Fires caused by rock falls are also important, bringing the incidence of natural fires to about 50% in both areas. The Californian statistics (49,6%) which includes the Mediterranean type chaparral, appears remarkably similar to these Cape records. Van Wilgen (1981-b, p. 33) refers to 16 state-owned plantation fires investigated in the Western Cape. Of these four (25%) started as a result of natural causes, two by lightning and two by falling rocks.

Further analysis of fire occurrence appears in Table 8. These fires include all, including human, causes, except the Swartberg column, which only features natural fires. Comparisons between the various forestry regions are facilitated by the October to March and the April to September totals at the bottom of the table, with percentage in brackets. The winter-rainfall, Mediterranean influence is strongly noticeable in the Western Cape, Southern Cape and Tsitsikamma, with respectively 73%, 66% and 79% of the fires occurring in the warmer summer months (Table 8). The

TABLE 7 NATURAL CAUSES OF VEGETATION FIRES

LOCALITY	YEARS RECORDED	TOTAL FIRES RECORDED	FIRES CAUSED BY LIGHTNING	PER-CENTAGE LIGHTNING FIRES	SOURCE
1. California	1943-47	7 781	3 863	49,6%	Leloup, 1953, p.14
2. West Australia	?	?	?	5,0%	Harris, 1964, p.10
3. Canada	1943-52	51 310	8 610	16,8%	Anon, 1956, p. 8
4. N-W. Canada	1953	109	29	26,6%	Anon, 1956, p. 8
5. South Africa	1970-79*	1 166	195	16,7%	Dept. of Forestry, 1970/79
6. Transvaal/Natal	1980	255	17	6,7%	Le Roux, 1981, p. 4
7. Western Cape	1958-74	53	19	35,8%	Bands, 1977, p. 251
Cedarberg			12 rocks	22,6%	Kruger, 1979, p. 27
8. Southern Cape	1951-77	170	81	47,6%	Horne, 1981, p. 56
Swartberg			3 rocks	1,8%	

* Statistics do not include the year April 1975 to March 1976

Eastern Cape and particularly Natal reveal a reverse trend with 68% and 93% respectively of fires burning during the dry winter months.

The occurrence of fires must be seen as the impact of a wide range of influences. Among these the direct climatic impact is probably the most significant. Phillips (1963, p. 91) mentions extreme drought and extended aggravating berg wind conditions as the major climatic influence affecting the Great Southern Cape fire of 1869. Vines (1977, pp. 116 - 117) refers to distinctive fire and flood cycles which he attributes and correlates to rainfall phases and sun-spot cycles ranging from very long-term to distinctive ten to eleven year and even shorter six to seven year cycles in Australia. Philpot (1977, p. 12) and Minnich (1977, p. 449) attribute the Californian chaparral vegetation as an adaption to fire, so does Bond (1980, p. 68) for the South African fynbos.

In the Cape fynbos, Kruger (1977, p. 235) has difficulty in determining natural fire frequencies. Bands (1977, p. 251) however implies that natural fires must have occurred at intervals of from six to forty years in the past. Moll et al (1977, pp. 473 - 474) refer to a natural fire interval along the Cape Table Mountain of between 30 to 50 years. This correlates with Zedler (1977, p. 452) who distinguishes highly variable fire cycles based on varying chapparral senescence of between 25 to 100 and more years in California.

The foregoing discussion was mainly centred around fire behaviour in the fynbos vegetation bordering onto indigenous forests. The forests themselves are as a rule too moist (mesophytic) to burn (Moll, 1981, p. 7), but it is the forest margin that has to bear

TABLE 8 VARIATION IN MONTHLY FIRE FREQUENCIES ON FOREST PROPERTY ALONG THE SOUTH AFRICAN COASTAL REGION, 1966 - 1975, AND A COMPARISON WITH THE SWARTBERG NATURAL FIRE INCIDENCE (Department of Forestry, 1977; Horne, 1981, p.56)

MONTH	SOUTHERN CAPE	SWARTBERG (NATURAL)	WESTERN CAPE	TSITSI-KAMMA	EASTERN CAPE	NATAL
January	22	21	37	9	7	0
February	16	14	23	7	1	0
March	11	8	17	13	0	0
April	10	3	12	1	1	0
May	4	2	7	1	1	3
June	7	0	5	2	7	11
July	14	1	4	1	24	37
August	6	2	3	6	17	42
September	5	2	15	2	6	24
October	6	4	17	5	12	9
November	17	12	19	9	3	0
December	17	15	14	5	3	0
TOTALS	135	84	173	61	82	126
October - March	89(66)	74(88)	127(73)	87(79)	14(32)	9(7)
April - September	46(34)	10(12)	46(27)	13(21)	56(68)	117(93)

the brunt of fynbos fire attacks (Phillips, 1963, p. 89). Bond (1980, p. 70) refers to the scarcity of the tree element in fynbos and relates this to fires. Both Van Wilgen (1980, p. 72) and Scriba (1976, p. 15) refer to the indigenous Widdringtonia cedars (respectively Widdringtonia cedarbergensis and W. nodiflora) in this regard with Scriba indicating natural growth modifications in W. nodiflora which are ascribed to natural fire survival measures inherant in that tree species.

3.5 Vegetation

Apart from Acock's broad veld type vegetation classification (Acocks, 1975), Phillips' Knysna forest-orientated successional classification (Phillips, 1931) and more localised and specialised studies such as that of the fynbos vegetation at Ruitersbos (Bond, 1981), the forest entity itself (Von Breitenbach, 1968 and 1974) and the study of the forest/fynbos edge (Van Daalen, 1980), the vegetation pattern of the Southern Cape as a whole has not yet been classified into detailed structural nor floristic units (Van Daalen, 1980, p. 48). The reasons for this appear to be the following:

(a) The complexity of the vegetation involved, particularly that of the fynbos;

(b) Taxonomic classification problems, mainly in the varied mountain fynbos expanse;

(c) the relative direct unimportance of fynbos and lower scrub forest from an economic point of view (Van Daalen, 1980, p. 49; Moll et al, 1980, p. 221);

(d) the relative inaccessibility of the steeper mountain slopes;

(e) the increased use of fire by man to remove the vegetation element for purposes of access, hunting or grazing or accidental fires, thereby changing the natural vegetation patterns;

(f) the construction or establishment of settlements, roads, agricultural lands and particularly exotic plantations, particularly of the coastal plateau to the foothill zone (Von Breitenbach, 1968, p. 116);

(g) the invasion of mainly exotic "invader" plants, such as species of the genus Pinus, Hakea and Acacia (Van Daalen, 1980, p. 48).

A brief resumé of the major natural vegetation classifications is provided.

3.5.1 Acocks' Veld Type Classification

Acocks (1975) recognises four major vegetation types in the Southern Cape (Fig. 20):

(a) The Knysna forest (Veld Type 4) which is the largest zone within the study area. It covers the whole central to eastern study area. Acocks (1975, p. 21) does not describe this veld type, but refers to Phillips (1931) in this regard.

(b) The False Macchia belt (Veld Type 70), which is the second largest vegetation zone of the study area and covers the steeper Outeniqua mountains. Acocks (1975, pp. 105 - 106) devotes two short non-descriptive paragraphs to this veld type, but he does classify it as equal to the true Macchia (Veld Type 69). Acocks distinguishes between two macchia types, the true "Fynbos" and an "Arid Fynbos";

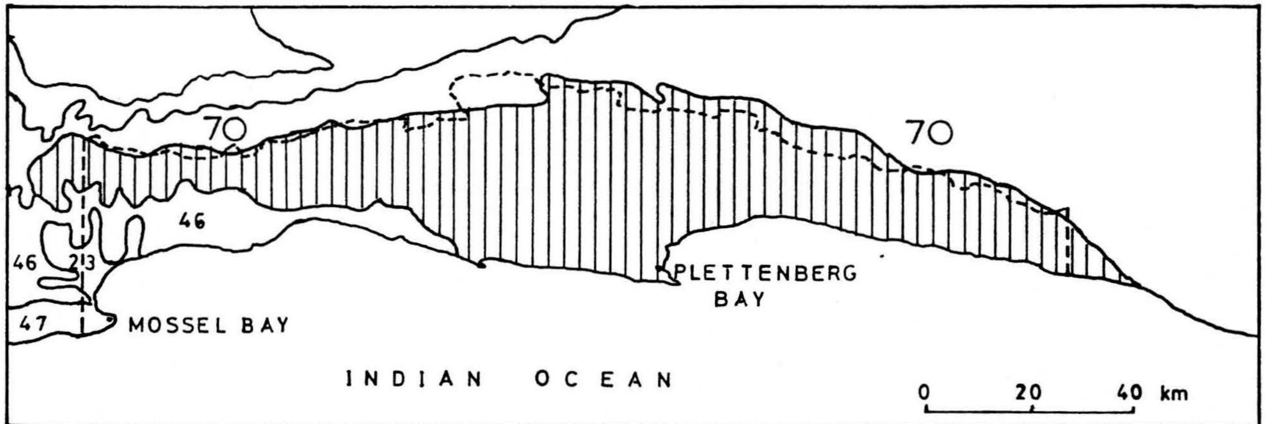

Fig. 20 Acocks' veld type classification for the Southern Cape. (Acocks, 1970).

	Knysna forest (veld type 4)
23	Valley Bushveld
46	Coastal Renosterbosveld
47	Coastal Macchia
70	False Macchia
	Boundary of study area

(c) the Coastal Renosterbos (Veld Type 46) and Coastal Macchia (Veld Type 47), located along the plains and coast respectively west from George and Mossel Bay. Both these veld types occur in dry areas, below 500 mm of precipitation per annum and have been extensively disturbed (Acocks, 1975, pp. 86 - 87);

(d) Valley Bushveld (Veld Type 23), north of Mossel Bay, which features mainly Karroid bush.

The latter three veld types (46, 47 and 23) have little impact on the forest locality.

3.5.2 Phillips' Plant Succession Classification

Phillips (1931, pp. 107 - 131), in describing vegetation patterns of the Knysna region, distinguishes between four broad-based plant-succession stages. He terms these the Hydrosere, Halosere, Psammosere and Lithosere, which all potentially lead to the formation of fynbos. From the fynbos again a succession to forest stages passes through scrub and bush stages. It is interesting to follow Phillips' classification, particularly that of the Hydrosere and the Lithosere, which both lead to a climax forest of the medium-moist type.

Phillips observes that the Hydrosere, which he associates with initial free water plant communities, leads to a typical hygrophilous fynbos through a successional sequence of Restiaceae (e.g. *Restio* and *Elegia* spp.), *Cliffortia* species, followed by the Bruniacea (e.g. *Berzelia* and *Brunia* spp.), the Ericaceae, the latter all freely mingling with each other. Further succession leads to the gradual dominance of the Proteaceae (e.g. *Protea*, *Leucadendron* and *Mimetes* spp.). This fynbos type follows through into distinctive tree element types, namely either *Salix capensis* (Cape willow) along the river banks, or *Strelitzia alba* (Wild banana) along southern aspects in the Tsitsikamma, or *Platylophus*/ *Cunonia* and *Virgilia* consocies as forerunners of a wet climax mixed forest type. The latter are evident in sheltered mountain valleys.

Both the Halosere and Psammosere are associated with the coast-line, the former with brack conditions prevailing mainly within tidal influence, the latter on sandy beaches and sandy elevated dune land, leading to Psammaphilous macchia, a distinctively coastal form of fynbos. Wiry grasses and fleshy succulents initiate this psammaphilous fynbos development.

In his discussion of the Lithosere, Phillips distinguishes between different plant successional types located on rocky coast, rocky plateau and rocky mountain, with a major distinction made between xerophytic northerly (Xerocline) and mesophytic southerly (Mesocline) aspects in the latter type. Both lead to distinctive fynbos types and may succeed through scrub and bush to climax forest.

3.5.3 The Forest and Non-Forest Vegetation Elements

3.5.3.1 The Forests

The forests have already been referred to and briefly described earlier in this chapter. It is however necessary to appropriately classify the forest vegetation. Geldenhuys (1982, p. 5), in a comprehensive study of the forests, describes the composition of the forest as consisting of 122 woody tree types as well as about 200 other associated plant species. He recognises three major forest zones, the mountain forests, the coastal forests and the plateau forests.

(a) The Mountain Forests

These are located on sheltered Southern aspects at higher altitudes. They represent wet to very wet forest types. Sixteen per cent of the Southern Cape indigenous forests are currently classified under this zone. As far as species distribution is concerned, Geldenhuys mentions the dominance of particularly *Cunonia capensis*, *Ocotea bullata* and *Alsophila capensis*. This is substantiated by statistics appearing in Table 9 where the first five species account for 77% of the total number of tree stems enumerated. Table 9 represents an enumeration undertaken in a typical wet mountain forest which is located 610 m above sea-level on a southerly aspect. Data represents an enumeration of all stems ten cm and more in diameter (at breast height = D.B.H.) within 44 plots each 10 m x 10 m. Only 18 different woody tree species were identified in this forest.

TABLE 9 TREE FREQUENCIES: WET TO VERY WET MOUNTAIN FOREST - TYPE: PLATBOS, GROENKOP FOREST (33°55' S x 22°33'E

NUMBER	SPECIES	PERCENTAGE FREQUENCY
1.	*Ocotea bullata*	25,4
2.	*Platylophus trifoliatus*	16,7
3.	*Cunonia capensis*	15,3
4.	*Halleria lucida*	11,8
5.	*Alsophila capensis*	7,7
6.	*Podocarpus latifolius*	5,8
7.	*Ilex mitis*	5,7
8.	*Rapanea melanophloeos*	2,9
9.	*Laurophyllus capensis*	2,7
10.	*Olea capensis var. macrocarpa*	2,6
11-18.	Others	3,4
		100,0%

(b) The Coastal Forests

These are associated with the coastal escarpment and the steeper slopes along the river valleys. These forests are normally dry forest to dry scrub types and represent about 36% of the Southern Cape forests (Geldenhuys, 1982, p. 5). Two enumerations were conducted to determine tree species composition, one at Herolds Bay (Table 10), with eleven sample plots each measuring 10 m by 10 m; all trees above 10 cm diameter (D.B.H.) were identified and enumerated; the other at Groenkop on a northerly aspect along the Kaaimans-river valley, where 55 sample plots were measured. Table 11 provides the floristic details of the latter enumeration.

TABLE 10 TREE FREQUENCIES: DRY SHELTERED COASTAL FOREST TYPE : HEROLDS BAY (34°03' S x 22°22'E)

NUMBER	SPECIES	PERCENTAGE FREQUENCY
1.	*Cassine peragua*	23,6
2.	*Pterocelastrus tricuspidatus*	13,5
3.	*Cassine aethiopica*	10,1
4.	*Sideroxylon inerme*	9,3
5.	*Cassine crocea*	8,4
6.	*Apodytes dimidiata*	6,7
7.	*Diospyros whyteana*	5,1
8.	*Canthium ventosum (syn. C. inerme)*	4,2
9.	*Maytenus heterophylla*	3,4
10-30.	Others	15,7
		100,0%

TABLE 11 TREE FREQUENCIES: DRY SCRUB FOREST TYPE: GROENKOP FOREST. (33°58' S x 22°32' E)

NUMBER	SPECIES	PERCENTAGE FREQUENCY
1.	Pterocelastrus tricuspidatus	20,9
2.	Apodytes dimidiata	6,8
3.	Olinia ventosa	6,8
4.	Gonioma kamassi	5,9
5.	Cassine peragua	5,7
6.	Lachnostylis hirta	5,2
7.	Olea capensis var. macrocarpa	4,8
8.	Curtisia dentata	4,4
9.	Rapanea melanophloeos	3,5
10.	Vepris undulata	3,5
11-48.	Others	32,5
		100,0%

A comparison between these two dry forest types reveals important similarities, namely dominance of Candlewood (Pterocelastrus), the Saffrons (Cassine species) and white pear (Apodytes). White milkwood (Sideroxylon) is a typical coastal tree type. In the coastal forests the first five species account for 65% of the 30 tree species identified, while river slope forests reveal a wider diversity of 48 species with the first five species accounting for 46%.

(c) The Plateau Forests

These cover the largest area, 48% of the total (Geldenhuys, 1982, p. 5) and represent the medium moist to moist forest types. Table 12 represents tree enumerations of 215 000 trees, 2,5 cm and thicker in diameter, which were measured and identified in the 1920's within 155 ha of sample plots representing forests at Stormsriver (23°55' E), Lottering (23°40 E), Blauwkrantz (23°35' E), Harkerville (23°10' E), Kaffirkop (23°10' E), Diepwalle (23°10' E), Gouna, Lilyvlei (23° E) and Sourflats (22°55' E). The first five species represent 47% of the total.

When comparing the three forest zones with each other it is only Pterocelastrus and Gonioma, which feature simultaneously as dominants (first five species) in the dry and medium-moist forest types. In all other cases the dominant tree species differ from each other.

In a tree stock enumeration of the Swartkop (Nxamalala) forests in Natal (Scriba, 1971, p. 13) a comparison of the first 20 species with that of the Southern Cape (Table 12), shows that only three species appear on both lists, and are reasonably equally represented. These are Halleria lucida (stocking respectively of 4,8% at Swartkop and 3,8% in the Southern Cape), Rapanea melanophloeos (respectively 1,2% and 0,8%) and Ilex mitis (1,0% in both regions).

Apart from the more dominant tree flora, a large range of less dominant flora exists in the forests, ranging from mosses, lichens and ferns to varieties of thorny shrubs and climbers. Von Breitenbach (1974, pp. 45 - 58) lists 16 ferns, 34 grasses and herbs, 26 shurbs, ten climbers and 11 epiphytes. Of particular interest are the dense forest floor consociations of herbacious species such as Piper capense, Trichocladus crinitus and Plectranthus species, which are commonly used as indicator plants for different forest types.

3.5.3.2 Fynbos

The term "fynbos" has replaced the older terms macchia, sclerophyll and heath in South Africa (Bands,

TABLE 12 TREE FREQUENCIES: SOUTHERN CAPE CLIMAX HIGH FORESTS. (Phillips, 1931, p. 183; (Phillips, 1963, p. 79)

NO.	SPECIES	COMMON NAME	PERCENTAGE FREQUENCY
1.	Olea capensis var. macrocarpa	Black Ironwood	13,2
2.	Gonioma kamassi	Kamassi	10,8
3.	Podocarpus latifolius	Real Yellowwood	8,6
4.	Pterocelastrus tricuspidatus	Candlewood	8,4
5.	Olea capensis var. capensis	Bastard Ironwood	6,3
6.	Burchellia bubalina	Wild Pomegranate	5,8
7.	Apopdytes dimidiata	White Pear	5,7
8.	Curtisia dentata	Assegai	5,2
9.	Platylophus trifoliatus	White Alder	5,0
10.	Cassine crocea	Saffron	3,8
11.	Halleria lucida	Tree Fuchsia	3,8
12.	Diospyros whyteana	Monkey Plum	2,9
13.	Ocotea bullata	Black Stinkwood	2,8
14.	Nuxia floribunda	Wild Elder	2,6
15.	Canthium obovatum	Quar	2,6
16.	Maytenus acuminata	Silky Bark	2,3
17.	Canthium mundianum	Rock Alder	1,8
18.	Ochna arborea	Cape Plane	1,4
19.	Maytenus penduncularis	Blackwood (indig.)	1,1
20.	Ilex mitis	Cape Holly	1,0
21.	Lachnostylis hirta	Coalwood	0,9
22.	Rapanea melanophloeos	Cape Beach	0,9
23.	Podocarpus falcatus	Common Yellowwood	0,6
24.	Cunonia capensis	Red Alder	0,6
25.	Other species		1,9
			100,0%

1983, p. 296), although the latter terms are still widely used overseas together with such terms as "chaparral" in California, "maquis" in France and more generally "heathlands" and "Mediterranean-type shrublands" (Specht, 1981, pp. VI - VII).

The most comprehensive description of the South African fynbos to date is doubtlessly by Kruger (1979). Kruger (1979, pp. 34 - 49) recognises three main fynbos vegetation zones, mountain fynbos, arid fynbos and coastal fynbos, with the latter structurally very much the same as the mountain fynbos, except that coastal fynbos occurs mainly on sands and limestones. Kruger describes the more diverse mountain fynbos communities in greater detail, distinguishing broadly between two zonal levels, a lower proteoid zone located along the mountain foothills, and an ericoid - restioid zone at higher elevations. He recognises four major mountain fynbos communities with 11 subordinate types. In broad terms Kruger's zonation follows a moisture gradient with the arid fynbos receiving from 200 to 400 mm of annual rainfall, the mountain fynbos from 500 mm to above 1 000 mm, while the coastal fynbos receives more moderate rainfall, probably between the above-mentioned extremes.

Bond (1981), in a study of the Ruitersbos area, located within the Southern Cape study area due north of Mossel Bay, recognises four major vegetation groups, arid fynbos, xeric proteoid shrublands, mesic-proteoid shrublands and ericaceous heathlands. In the Swartberg range north of Oudtshoorn, he recognises five main groups. These are the four groups found at Ruitersbos, although modified with some floristic and locational differences, and a fifth group which features succulent karoid vegetation. In broad terms Bond's four main

Ruitersbos vegetation groups are summarised as follows (Bond, 1981, pp. 93 - 119):

(a) Arid fynbos

This community occurs at lower elevations of around 600 to 750 m mainly on dry northern aspects. It is dominated by ericoid shrub with dryland *Felicia* and *Phylica* species the distinguishing floristic feature.

(b) Xeric Proteoid Shrublands

This group is confined to mid- and lower altitudes, i.e. from about 600 m to 1 000 m, and mainly occurs on northern aspects with distinctive proteoid plant indicators. These include *Protea lorifolia*, *P. repens* and *P. nitida* (Waboom), the latter providing for the distinctive waboomveld phenotype. Other prominent indicator species are the very distinctive bright-yellow *Leucadendron salignum* as well as *Elegia galpinii*.

(c) Mesic Proteoid Shrublands

Communities belonging to this group occur on both northern and southern aspects at a wide range of elevations. The Proteaceae are again dominant, with the following species featuring as prime indicators: *Protea nerifolia*, *P. aurea*, *Leucadendron eucalyptifolium*, with *Erica viridescens* as main Ericoid element.

(d) Ericaceous Heathlands

These occur at higher elevations on southerly aspects and are dominated in different communities by such indicator species as *Restio anceps*, *Erica arachnoidea*, *Mimetes cucullatus*, *Protea cynaroides* and species of the family Bruniaceae.

There has recently been considerable interest about the question of successional phases in fynbos. Kruger (1979, p. 52), modified for the Southern Cape by Bond (1980, p. 68), identify five distinct phases (Table 13), namely annuals, herbacious plants, low shrub, tall shrub and the senescent stage, which is however outlived by a tree element in certain areas. The succession commences after fynbos has been destroyed by fire. The fynbos succession depends on specific fire cycles to terminate the senescent phase at an early stage. Bond (1980, p. 71) concludes that over-mature fynbos has a detrimental effect on the regeneration potential of the Proteaceae.

TABLE 13 FYNBOS SUCCESSION (Kruger, 1979 and Bond, 1980)

PHASE TYPE	AGE (yrs)	BRIEF DESCRIPTION
1. Initial phase	0 - 1	Annuals appear and dominate. Germination of almost all seed. Vegetative regeneration occurs.
2. Youthful	2 - 4	Herbacious and Graminoid stage. More permanent shrubs emerge. Canopy height almost pre-burn level.
3. Transitional	5 - 10	Lower shrubs reach reproductive maturity. Tall shrubs emerge above canopy.
4. Mature	11 - 30	Tall shrubs reach maturity. Lower shrubs die. Dead litter accumulates.
5. Senescent	31 and over	Shrub mortality accelerates. Tall shrubs collapse. Maximum dead biomass accumulation. Trees start dominating.

The gradual domination of certain fynbos sites by trees is not mentioned in Kruger and Bond's successional phases. Kruger (1979, p. 29) does, however, mention a scarcity of tree flora in fynbos. Van Wilgen (1981-a, p. 50) is more specific and features an emerging tree element after about 30 years. Moll et al. (1980, p. 227) and Campbell, McKenzie and Moll (1981) conclude that there is a possibility that fynbos once supported a larger tree element. The tree element can broadly be divided into those favouring warmer and drier northern aspects, such as Protea nitida, Protea repens and even Cliffortia ruscifolia and those favouring cooler and moister southern aspects, such as Widdringtonia nodiflora and Protea neriifolia (Van Wilgen, 1981-a, pp. 47 - 49).

3.5.3.3 The Forest/Fynbos Edge

Finally a remark on the merger between forest and fynbos, i.e. the forest edge or fynbos edge from whichever angle viewed. According to Van Daalen (1981, p. 22) the fire-adapted fynbos encroaches upon and reveals tendencies of gradually replacing portions of the indigenous forests, once the latter are destroyed by fire. He also revokes Phillips' hypothesis that fynbos is a seral in forest succession by stating:

> "Fynbos is not a seral in the indigenous forest succession as has been suggested in the past. Fynbos will not develop into forest within a reasonable time, i.e. 50 to 100 or even 200 years."

The present scarcity of trees in the fynbos (Moll et al, 1980) appears to also substantiate this point, provided fire is permitted to burn fynbos, and with that damage the forest edge at regular intervals. Van Daalen's findings are largely based on research work done in so-called fynbos "islands" which are located within the heartland of the indigenous high forest (Van Daalen, 1981, pp. 14 - 15). The origin of these islands is not properly explained yet. It is maintained that the natural protective strength or devices of the forest ecotone lie not in its heartland, but on its margins.

The forest/fynbos edges are essentially located along the foothill to steeper mountains, as well as in protected river valleys incised from the mountain ranges seawards. This impact zone between fynbos and forest, and as far as the forest is concerned, this impact zone between fire and forest, has not yet been properly investigated. It may yet provide the key to many answers. A preliminary investigation into this impact zone was conducted due north of George and along the north-eastern Platbos near Saasveld. The following brief resumé describes broad findings made:

> The direct impact of fires on the present forest location patterns concerned is difficult to gauge, because of extreme scarcity of records on the time and location of past fires. Nevertheless the mountain forest patches and their immediate environment, particularly in the vicinity of George, reveal fairly distinct successional plant community stages, which have mainly been caused by previous fires. Fig. 21 represents four successional stages progressively identified from the fynbos towards the forest proper. These are also present in most other forest patches along the Outeniqua slopes in the vicinity of George. These four stages are:
>
> (a) <u>A low ericoid shrub belt</u>, located on shallow, azonal Table Mountain Sandstone, consisting of the general flora of the fynbos community beyond, though also interspersed with particu-

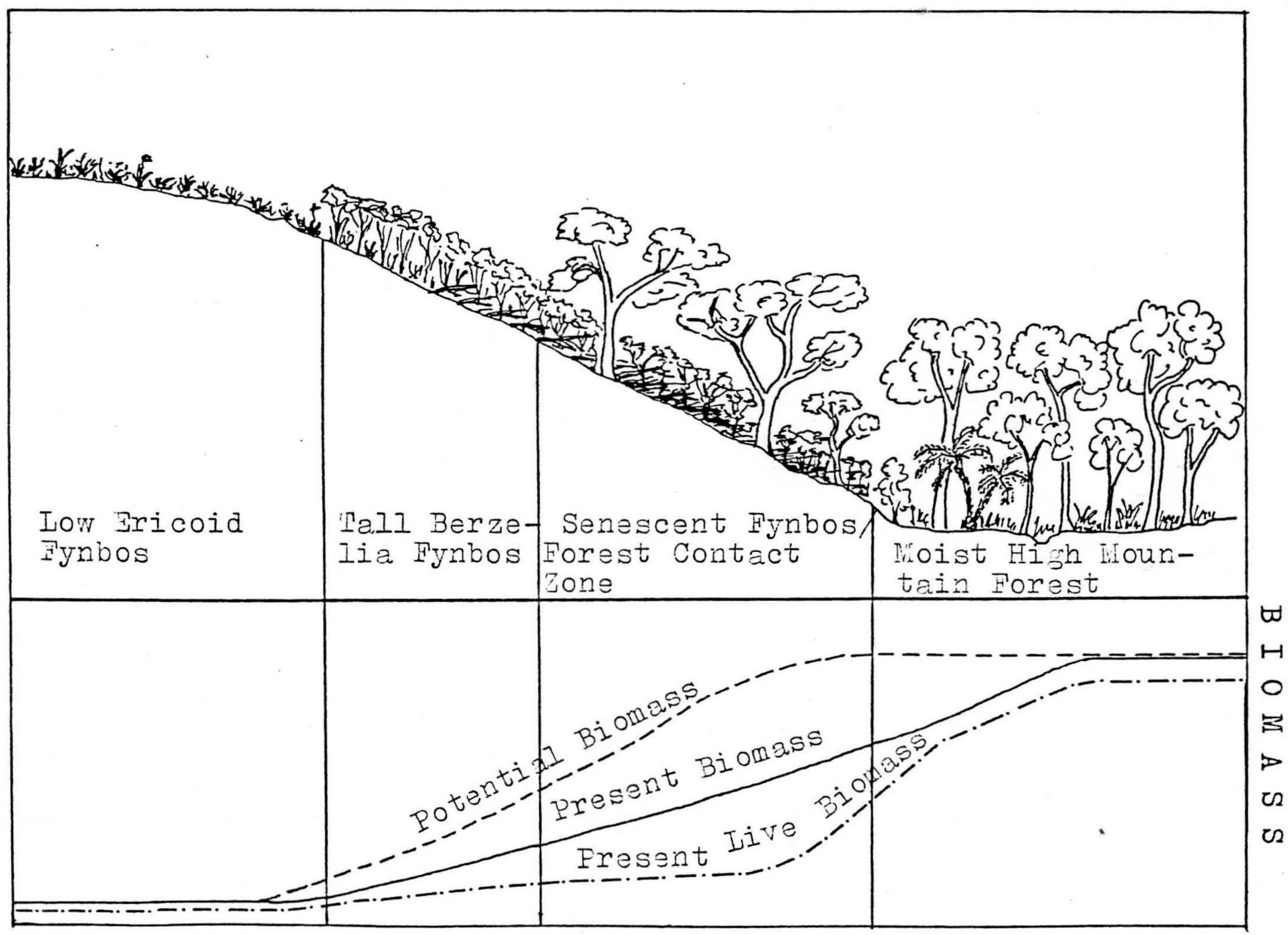

Fig. 21

Successional vege= tation stages: Southern Cape mountain forests larly Pteridium (Bracken) and other ferns, more so towards belt (b) below. It is considered highly unlikely that this belt was ever forested in the past, mainly because of the extreme shallowness of the soils. This belt is termed "Low Ericoid Fynbos" in Fig. 21;

(b) a belt of taller fynbos, mainly represented by the family Bruniaceae and up to three metres high in places (refer to "Tall Berzelia Fynbos" in Fig. 21). This fynbos is generally interspersed with low bracken and such initial pioneer species as Laurophyllus capensis and smaller Virgilia oroboides towards belt (c) below. Belt (b), frequently up to 50 m wide, is considered to represent potential earlier forest margin, i.e. before being affected by man's impact of repeated fires;

(c) a belt dominated by a Virgilia oroboides stratum, with Laurophyllus capensis and emerging Cunonia capensis as substratum, interspersed with degenerated masses of partially live fynbos of the Bruniaceae type which tend to stifle growth in the senescent stage. This belt is considered to have been former high forest and may again develop towards this if left undisturbed for a length of time. This belt should be regarded as the current contact zone between forest and fynbos. Many of the forest patches along the mountain slopes in the vicinity of George feature this successional stage prominently. This belt is described as the "senescent Fynbos/Forest contact zone" in Fig. 21;

(d) the forest stage itself, in this case a typical wet mountain forest type, consisting mainly of Cunonia capensis, Ocotea bullata and Platylophus trifoliatus as the dominant tree stratum, with Halleria lucida and Alsophila capensis, the tree fern, as understorey (Fig. 21; Table 9). This stage qualifies as "moist high mountain forest" in Fig. 21.

The graphic representation of the live, dead and total biomass (Fig. 21) is based more on observations than measurement and reveals the following generalised trends or assumptions:

a proportional increase in floral biomass from the shrub fynbos (stage a) to the high forest level (stage d); a marked increase in dead biomass in the contact zone between forest and fynbos in senescent sites (stage c); an assumption that given sufficient undisturbed time, measured in centuries rather than decades, the forest/ fynbos contact zone (stage c) has a potentially higher (live) biomass level than any of the other growth stages mentioned; it is assumed that this potentially high biomass level will consist to an increasing extent of live woody flora, once the senescent fynbos stage has been surpassed.

It is hereby assumed that fynbos has the edge on and replaces forest vegetation if it is aided by repeated (time) fires (destruction) in the contact zone, but that forest can re-establish itself in this area given the time. This assumption only applies to the wet mountain forests fringed by Virgilia ororboides, and not to fynbos islands in the forest heartland. Fynbos maturity and senescence is measured in two to four, possibly six decades (Bond, 1980; Kruger, 1979; Moll et al, 1980). After how many years will a mountain forest be capable of reaching maturity, not to mention senescence? Indigenous forest succession to a mature climax and a term such as "indigenous forest senescence" have yet to be investigated.

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CHAPTER 4

THE FOREST ENVIRONMENT : HUMAN LANDSCAPE

The human impact on a natural ecosystem is influenced by two factors in particular (Haggett, 1979, p. 168): man has dramatically increased in numbers and he has used technology to modify "natural" food chains. This has resulted in man dominating ecosystems with the latter serving the former's increasing needs. As a result of such impact, the environment has experienced drastical change in particularly macro-fauna, where animals useful to man have increased at the expense of so-called "non-useful" species; the plant kingdom, where original floristic patterns have been destroyed, changed or replaced; and the direct change of primary environmental patterns, such as changing hydrological cycles by the diversion of water from natural river systems.

4.1 The Historical Background

The human landscape of the Southern Cape is first of all viewed from the historical point of view, implying the impact of man on the study area with lapse in time. In this regard the forests themselves have played an important and active role and for a long time were one of the few available, exploitable natural resources (Grewar, 1982, p. 155). The history concerned has been documented in numerous publications, the more noteworthy being Brown (1887), Sim (1907), Phillips (1931), Laughton (1937), Phillips (1963) and Von Breitenbach (1968). Table 14 is a brief historical resumé of the most important events during the past 200 years. The history of human occupation and particularly the resultant impact on the forests can be divided into three fairly distinct phases, based not so much on historical events, than on the use of and treatment meted out to the forests.

4.1.1 Preamble - The Period Prior to 1780

Prior to 1711, Hottentot tribes inhabited the more open central to western sectors of the study region. The Gouriqua and Attaquas inhabited the plains west of present-day George and were primarily cattle herdsman (Von Beitenbach, 1968, p. 4). Further east along the George to Knysna plateau other tribes were primarily engaged in hunting, honey collection and food-gathering (Inskeep, 1978, p. 152). Both appear to have used fire to further their respective aims and these fires must be regarded as the first more significant impacts the forests experienced alongside their perimeters at the hands of man.

Sim (1907, p. 43) states that the Hottentot and Bushman inhabitants do not appear to have had any interest in the forests themselves, so that no form of timber exploitation is implied for this earlier period. Numerous Earlier Stone Age implements (Kirkman, 1974) and old rock paintings found along the present forest edge in the vicinity of Saasveld, indicate yet earlier occupation of the plateau region by man. Inskeep (1978, pp. 104 - 114) mentions seasonal migratory habits of early Southern Cape inhabitants in search of food during the Holocene, implying movement from the coast with its seafood diet to inland meat and plant food resources. The year 1711 can be regarded as the year of discovery of the Southern Cape forests by the Dutch, though it took a full 66 years before frontiers opened sufficiently to enable potentially valuable timber resources to be exploited and transported to more distant markets.

TABLE 14 THE INDIGENOUS FORESTS OF THE SOUTHERN CAPE, A SUMMARY OF IMPORTANT EVENTS OVER THE PAST 270 YEARS (Grewar, 1982; Von Breitenbach, 1968; Laughton, 1937; Tyson, 1971)

YEAR	DESCRIPTION
1711	Reports of large forests in Outeniqualand reach the Cape.
1776	Establishment of Woodcutters Post at George.
1787	Woodcutters Post established at Plettenberg Bay.
1788	Mossel Bay established as port mainly for wheat.
1811	Town of George founded.
1812	Forests exploited for Royal Navy.
1817	Knysna established as timber exporting port.
1835	Increased demand of timber for Great Trek.
1846	Worked-out forests sold by auction; Crown forests felling rights by Licence.
1847	Extreme forest destruction. Crown forest closed.
1856	Crown forests re-opened because of timber shortage.
1869	The "Great Fire" which destroyed much forest.
1874	Captain Harrison appointed Conservator.
1880	Count de Vasselot appointed Superintendent of Forests.
1888	The first Forest Act passed for George.
1907	Railway line opened from Mossel Bay to George.
1913	Railway line from George to Oudtshoorn.
1922	Intensive Forest Research launched at Diepwalle.
1939	Registered Woodcutter System comes to a close.
1964	Indigenous Forest Research started at Saasveld.
1966	Multiple - Conservation Management System inaugurated by Research.
1972	Multiple - use Management and Planning included in Forest Regional Management.

4.1.2 The Forest Devastation Period (1780 - 1880)

From 1780 onwards the ensuing 100 year period can rightfully be termed a forest exploitation and devastation phase. This period represents an onslaught on the forests by the early settlers, from which the forests have not since recovered. This onslaught was a multi-purpose one. Marginal forests were cleared for agricultural lands, particularly along the plateau regions; trees were recklessly felled for timber, the actual felling operations often doing more harm to surrounding trees than the actual timber subsequently removed (Sim, 1907, p. 43); and fire was used to obtain grazing, to hunt or to clear the mass of unused vegetation for further access. This onslaught on the forests was mainly directed from the south and west, although fires must have spread with relative ease into the mountain grasslands and fynbos and thereby affected the northern forest frontiers as well. The impact of this phase on the forests can to some extent be gauged by the following dates and activities from Table 14:

In 1776 a Woodcutter's Post was established at George; timber was transported mainly by ox-waggon westwards to the Cape Peninsula and later northwards across the Little Karoo to inland markets;

In 1787 a Woodcutter's Post was established at Plettenberg Bay with direct sea-shipment facilities to Cape Town;

In 1788 Mossel Bay established a port for particularly wheat shipments, although timber was also exported to a limited extent;

In 1817 Knysna was established as a timber exporting port.

Most reports mention the extremely intensive, uncontrolled and wasteful exploitation practices during the period 1830 to 1870, when the first conservation measures were introduced (Brink and Van der Zel, 1980, p. 15). Phillips (1931, p. 103) refers to the period 1822 - 1882 as a period of forest devastation, forest abuse and reckless felling. Brink and Van der Zel (1980, p. 15)mention that this period of forest "vandalism" was experienced elsewhere in the indigenous forests of South Africa as well.

1869 is the year of the Great Fire, which, though possibly overrated to some extent (Phillips, 1963, p. 91), can be regarded as culminating this phase through its devastation of the perimeters of the forest heartland. Brink and Van der Zel (1980, p. 15) also mention an earlier devastating fire dating to 1865. The fires are likely to have been aggravated by very wasteful cutting practices, described by the Superintendent of Woods and Forests in 1883 (Sim, 1907, p. 43) as wasting "... 27 times as much wood as has been used ...", resulting in masses of dry fuel being available. It appears from reports (Phillips, 1963, p. 91), that most of the forest damage occurred in the vicinity of Knysna, although the fire burnt from Riversdale to Humansdorp (Von Breitenbach, 1968, p. 20).

Some important indications of the earlier location pattern of the forests can be arrived at from Captain Jones' Admiralty Report of 1 November 1812 (Brown, 1887, pp. 9 - 10), which states:

> "From Plettenberg Bay the nearest point of the forest is about 10 or 12 miles (16 - 19 km) ...",

and

> "... 7 or 8 miles (11 - 13 km) east of Keurbooms, commences the Tzitzikama forests. ... Mossel Bay is a great distance from the forests ..., about 42 miles (68 km) ...".

These distances in fact still apply today.

4.1.3 The Period of Controlled Exploitation (1880 to date)

The human onslaught described, led to a gradual realistation that the forests were indeed exhaustible. A more stable form of forest management system was introduced with the appointment of Count de Vasselot de Régné in 1880 (Grewar, 1982, p. 156). This management system is aptly described by Hutchins (1893, p. 129) as the "Selection Felling System". This implies a practice whereby forests were first of all surveyed by officials of the Forestry department; thereafter divided into so-called Series, the largest working group; each Series was subdivided into 40 Sections, each 100 acres in area, of which one was exploited (worked through) per year. Knysna had 13 such Series, which involved a potential total area of about 20 000 ha managed under this system. Hutchins refers to the system applied before 1883 as "... each woodcutter selected what he wished to fell." He indicates a strong conservation impact when he refers to the practice in 1891 of planting "12 young trees" in the Government Forests of Knysna for each tree removed, although these young trees appear to have been exotic species (Von Breitenbach, 1968, p. 59).

The main reason for gradual control over the uncontrolled devastation phase lies in the fact that from 1872 more "responsible self-government" and the establishment of exotic pine and eucalyptus plantation were introduced (Brink and Van der Zel, 1980, p. 16). One major problem however remained, namely the woodcutters who made a living from the proceeds of the forests. Brink and Van der Zel (1980, p. 17) discuss this problem, which was of socio-economic-political nature.

In 1914 the woodcutters were eventually required to register. One-thousand one-hundred and ninety-six registered and although restricted to 25 m^3 per woodcutter per year, this timber volume was too much to be removed from the forest at a sustained rate, and too little to make a living on for each woodcutter.

But numbers were dwindling. By 1920 there were 831 woodcutters left, by 1932 483, by 1934 341 and in 1939, 272. The latter were given a pension and the option to work for the Department of Forestry. With that the woodcutter system came to an end. From 1939 up to the present, the forests have been protected from further misuse and within the past two decades a more active multiple-use conservation phase has evolved (Von Breitenbach, 1972, p. 39).

4.2 Indigenous Forest Timber Utilisation

A brief indication of the quantities and types of timber exploited in the past, serves to reveal the utilisation importance of the forests. Statistics on total timber volumes extracted are scarce and not very reliable. Table 15 features six different sources which provide some indication of the quanitities of timber extracted. The information given for the earlier history is based on numerous old reports, noteably Rex's Report of 1841 (Phillips, 1963, pp. 23 - 24), which provides accurate information on the shipment of timber from the Knysna harbour for the period 1821 to 1839 as well as for shipment from Plettenberg Bay; Dutton's Report of 1855, which provides information for the George area, and the reports of Brown (1887), Captain Harrison for the 1860's and 1870's and Count de Vasselot for the 1880's.

Table 15 however reveals certain anomalies that need to be explained. It appears that the timber volume for the period 1772 - 1881 quoted by De Villiers (1951) and Phillips (1963), are those of partly converted timber, i.e. not those of round logs, but sawn-up plank or railway sleeper products. Timber exploitation volumes are however normally expressed in round log form. Von Breitenbach (1968, p. 19) mentions this problem and his estimate of 19 830 m^3 per year for the period 1817 - 1839 (Table 15) is based on the conversion process. A second problem mentioned in literature in this regard is the extremely wasteful nature of felling (Sim, 1907, p. 43). The Superintendent of Woods and Forests (1883) is quoted as having mathematically calculated that there was a waste of 27 times the timber used, meaning a 4% recovery and 96% going to waste.

On the whole it appears from Table 15 that the forests yielded an average 3 000 to 4 000 m^3 of processed timber per annum within the period ending 1890, and a probable equivalent of between 8 000 to 12 000 m^3 of timber in the round; that the period 1890 to the 1940's meant an increase in timber yield to an average 13 000 m^3, before protective and conservation measures in the after-War period to date assured a drop to about 4 000 m^3 in the round. The statistics which appear on Table 15 in general apply to old "crown" forest land, more or less the equivalent of the present-day state forests.

The annual reports referred to in Table 15 provide information on which tree species were most favoured during exploitation. Reports from 1889 to 1905 (17 years) show that of the total respective timber yields, yellowwood accounted for 52,3%, stink-

TABLE 15 TIMBER VOLUMES EXTRACTED FROM THE SOUTHERN CAPE INDIGENOUS FORESTS (Sources provided)

PERIOD	NUMBER OF YEARS	TIMBER VOLUMES (in m^3 per year)					
		De Villiers 1951 p.6	Von Breitenbach 1968 p.18	Phillips 1963 p.23	Laughton 1937 p.88	Dept. of Forestry Annual Reports	Sim 1907 p.27
1772 - 1841	70	1 416					
1817 - 1839	23		19 830	8 050*			
1842 - 1881	40	2 832					
1882 - 1889	8	4 020					
1882 - 1890	9				4 020		
1889 - 1900	12						9 367
1891 - 1900	10				9 680		
1895 - 1900	6					11 194	
1890 - 1938	50	9 316					
1901 - 1910	10				11 750		
1901 - 1909	9					12 056	
1911 - 1919	6					12 612	
1921 - 1930	10				13 310		
1922 - 1929	7					13 808	
1939 - 1948	10	7 646					
1949 - 1958	10					5 340	
1959 - 1967	9					3 012	
1969 - 1978	7					4 026	

NOTE:

1) * The 8050 m^3 was calculated on the following basis: 1 100 tons per year shipped from Knysna; a similar shipment from Plettenberg Bay; 2 000 loads cut annually in the George Forests (Phillips, 1963, pp. 23 - 24);
1 ton = (60 to) 65 cub. ft. = 1,84 m^3 (Von Breitenbach, 1968, p.19);
1 load = (50 to 80) 70 cub. ft. = 1,98 m^3 (Phillips, 1963, p.27).

2) Department of Forestry reports referred to, include all annual government reports from 1895 onwards, in which forestry activities are accounted for.

wood for 13,1% and black ironwood for 10,7%. For the period 1906 to 1929 yellowwood accounted for 50,4%, stinkwood only for 4,4% and black ironwood for 11,6% of the total yield. More recent figures (Department of Forestry, 1972, 1973, 1975 - 1977), reveal yellowwood accounting for 29% of wood sold and stinkwood and ironwood each 10%.

4.3 The Land Utilisation Pattern

The Southern Cape study area can broadly be divided into five land use types (Tyson, 1971, p. 18), namely indigenous forests, exotic tree plantations, agricultural land use areas, mountain and coastal fynbos and nucleated settlement areas (Fig. 22). These types follow a reasonably set pattern of narrow to broader belts which run parallel to each other as well as the coast-line, viz.:

4.3.1 The Indigenous Forests

These are concentrated as a belt more or less centrally located between coast-line and the mountain crest. From calculations made (part 2.3) the Southern Cape study area as a whole has an area of 447 000 ha and the indigenous forest area comprises about 15% thereof, namely 65 000 ha. The current management objectives can be described as "multiple-use" objectives and six management classes are readily recognisable, particularly within state forests (Grewar, 1982, p.158). These classes are briefly explained below:

(a) Production Management Class

This covers about 10% of forest area (Geldenhuys, 1982, p. 6) and represents moist high forest where timber is extracted according to the selection system. The timber is graded and sold either by public auction or by tender, the grades being "Prime" representing the best quality, "average", "merchantable" and "serviceable", in decreasing grades of quality. The former two, representing 22% of the total volume (Grewar, 1982, p. 161) are sold by public auction, the latter two are sold by tender.

(b) Protection Management Class

This is the bulk of the drier and wetter forests, comprising between 70 - 80% of the forests, which are maintained in their natural state and which are protected against invasion by exotic plants. Only dead or windfallen trees are occasionally harvested.

(c) Reconstruction Class

This refers to re-establishment of forest along the forest edges or in forest clearances by indigenous tree planting. Geldenhuys (1982, p.8) mentions 129 ha of forest were reconstructed during the years 1968 to 1972 alone. Areally this class is limited to a few hundred hectares.

(d) Recreation Management

During the past decade numerous picnic spots, scenic spots, and forest walks were established to answer the need for outdoor recreation, particularly for city dwellers.

(e) Research Management

This class refers to areas set aside for ecological and silvicultural research.

(f) Nature Reserves

Areas declared nature reserves as a rule remain undisturbed, except for the eradication of invader plants. It is envisaged that all in all about 16% of the local forests will be declared nature reserves in due course.

4.3.2 The Exotic Plantations

The location of the plantations are closely associated with that of the indigenous forests. Plantations are located both north and south of the forests, but mainly north (Fig. 22), where pine plantations do well on the more acidic sandstones. The plantation area is about 70 000 ha (Von Breitenbach, 1968, p.2) with 48 500 ha growing on 27 government-owned forest reserves while the remaining 21 500 ha are located on private

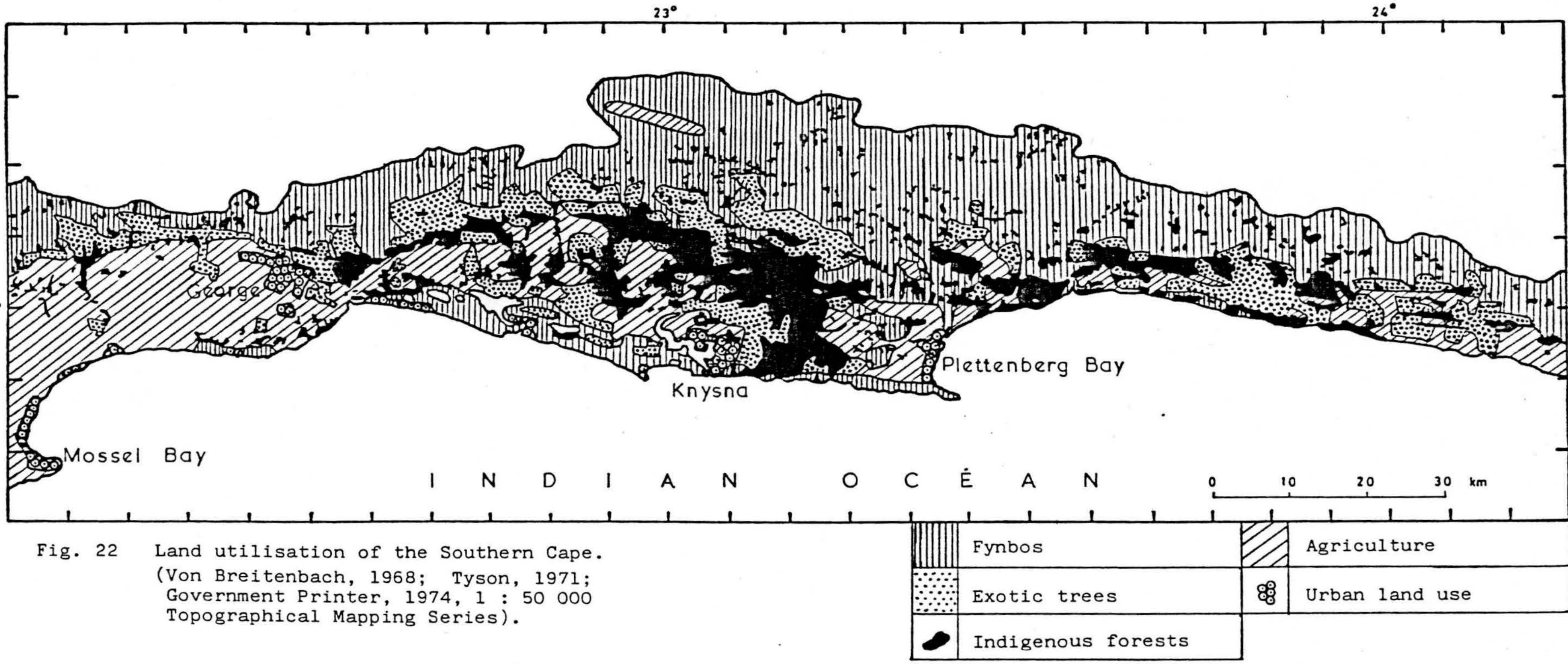

Fig. 22 Land utilisation of the Southern Cape.
(Von Breitenbach, 1968; Tyson, 1971;
Government Printer, 1974, 1 : 50 000
Topographical Mapping Series).

land. Barnard (1982, p. 245) mentions a total plantation area of 74 111 ha for the Southern Cape as a whole, of which 67 654 ha are pine trees, 5 473 ha gum species, the remainder being constituted of wattle, poplar and other hardwood species. A few of these plantations are however located outside the study area, such as Kromrivier close to Humansdorp, so that an area of 70 000 ha appears acceptable. Pine plantations were established as early as 1883 in the Knysna area (Schroeder, 1982, p. 113) and blackwood in 1889, but particularly during the period 1909 to 1914 (Von Breitenbach, 1968, p. 158). In 1891 Conservator Hutchins planted 96 000 gum, pine, wattle and oak trees within the indigenous forests, but this practice was soon abondoned.

The early exotic tree plantings were mainly established by forest conservators to safeguard the endangered indigenous forests. Before such plantations could become productive, South Africa had to import timber. The Cape Colony alone imported 140 000 m^3 of timber during 1896 (Sim, 1907, p. 70). The aim to become self-sufficient has however since been realised (Laurens, 1982, p. 138).

One large problem associated with exotic plantations and the introduction of exotic plantgrowth in general, is that of invader plants, which give rise to management problems in plantations, in indigenous forests and particularly in mountain fynbos catchment areas. Le Roux (1982, p. 187) mentions that about 45% of the Southern Cape pine plantations are invaded and threatened by such species as <u>Acacia mearnsii</u> (black wattle), <u>Acacia melanoxylon</u> (blackwood), <u>Eucalyptus</u> species, <u>Rubus</u> species and <u>Gleichenia polypodioides</u>. Owen (1983, p. 350) refers to <u>Hakea</u> species, <u>Pinus</u>

species, _Acacia cyclops_ and _Acacia cyanophylla_ as invading the mountain and coastal dune vegetation, in fact 384 000 ha of mountain catchment was infested by _Hakea_ species before eradication programmes were introduced.

4.3.3 The Mountain and Coastal Fynbos

The mountain fynbos is almost entirely located within forest reserve area. Forest reserves cover a total area of approximately 237 000 ha (Von Breitenbach, 1968, p. 2), which is 50% of the Southern Cape study area. It is estimated that about 46% of the study area is covered by mountain and coastal fynbos as well as unproductive coastal dune - and wastelands. The management objectives with the extensive mountain fynbos according to Seydack (1982, pp. 151 - 153) are the following four:

(a) _Water Conservation_, the aim being to conserve maximum water for sustained and high quality river flow. The Southern Cape study area features 18 larger river catchments, of which the Keurbooms catchment is the largest and covers about 110 000 ha, or 25% of the study area, the Swartvlei catchment and Knysna river catchment each covering about 43 000 ha, i.e. 10% of the study area, but the Kaaimans river catchment 13 300 ha (3% of the total study area) is probably the most important since George is fully dependent for its water on the old Swartriver Dam and the modern Garden Route Dam.

(b) _Recreation_

Momentarily the Outeniqua Hiking Trail is the only significant recreational facility located in the mountain fynbos. This trail was opened in 1976 and for the period 1977 to 1980 an average of 10 500 hikers used this trail per year (Cooper, 1982, p. 259). A reduction in the number of hikers during 1980 to 8 578 is possibly due to the fact that other hiking trails have subsequently been opened, noteably the Hottentots Holland-, Swellendam- and Tsitsikamma trails within the Cape Province.

(c) Nature Conservation

The Cape fynbos is the smallest of the six recognised floristic kingdoms of the earth (Seydack, 1982, p. 152). This places a great responsibility on conservation bodies and the owners of properties concerned to preserve the very diversified floral and faunal associations.

(d) Other Land Use

Flower picking, honey-tea picking and grazing, all on a very limited scale, are the only noteworthy agricultural practices possible in the large mountain fynbos expanse. The coastal fynbos and dunelands tend to develop more and more into nucleated settlements, with coastal holiday resorts featuring prominently.

4.3.4 Agricultural Land Use

This represents approximately 20% of the land and is mainly located on the coastal platform (Tyson, 1971, p. 18). Farmlands appear as larger units west of George, but eastwards the land is broken into more frequently by deep river incisions and the agricultural land pattern appears fragmented. The farming practices range from wheat farming in the vicinity of drier Mossel Bay, to the cultivation of fodder crops, intensive vegetable farming, the cultivation of hops, fruit orchards and grazing in the George/ Knysna area. Much of the farming east of George must be seen on the subsistence level, based mainly upon the limited farm sizes because many small-holdings are owned by elderly, frequently retired, people.

4.3.5 Nucleated Settlements

The remaining 3% of land represents built-up areas. These nucleated settlements can be directly associated with their past. The four timber posts or ports of timber export mentioned earlier, namely Plettenberg Bay, Knysna, George and to a lesser extent Mossel Bay, nowadays constitute the principal urban centres. Numerous villages and hamlets dot the settlement map around these towns (Fig. 4), which indicate a characteristic rural population pattern. Many of these villages can be traced to a forest-orientated origin (Tyson, 1971, p. 17), such as the villages along the "old Cape" road from George via Woodville, Karatara and Barrington.

4.4 The Population Pattern

"Forests precede a population, and deserts follow it." (Brown, 1887, p. 208). The above quotation by Count De Vasselot in a Report of Operations for the year 1881 may fortunately not fully apply to the Southern Cape indigenous forests, although it was used in this context, yet the impact of "population" has posed such a threat for the past two centuries. More than 90% of the six-million people populating the Cape Province, live in the coastal zone (Heydorn and Tinley, 1980, p. 62). Of these 5,4-million people only about 100 000 live in the Southern Cape (Department of Statistics, 1982).

From Fig. 4 it can be noted that the entire northern mountainous half of the study area, with the exception of the upper-Keurbooms catchment (Die Vlug van Speelmanskraal) is sparsely to unpopulated. The indigenous forest appears to be the main dividing feature between the populated plateau and unpopulated mountains.

The Southern Cape has maintained a reasonably large, though gradually declining, rural population. This is evident from Fig. 23 which reveals a shift towards the urban of late particularly in the George magisterial district. The Knysna rural population pattern has however remained very steady since 1946, when both the George and Knysna magisterial districts featured a 63% rural population.

Two aspects concerning population trends need mentioning, since both are of great socio-economic importance. The first concerns population trends of the White and Coloured people in both the George and Knysna magisterial districts. Whereas the populations of both these groups were fairly equal during 1936 at 50% of the total, namely 20 925 White to 20 356 Coloured people, the 1980 population census show the White to have shrunk to 27% of the total, while the Coloured population has risen to 63% (Department of Statistics, 1982). The second factor of importance is the phenomenal growth that the Southern Cape has experienced within the past decade, particularly tourism, trade and investment in general. The George Municipality (1983) in a press release, feature the following statistics:

> 680 000 tourists visit the Southern Cape annually; within the years 1981 and 1982 building plans for 407 new houses were approved; in 1957 George had 26 factories, in 1976 it had 46, while the figure rose to 83 factories in 1982.

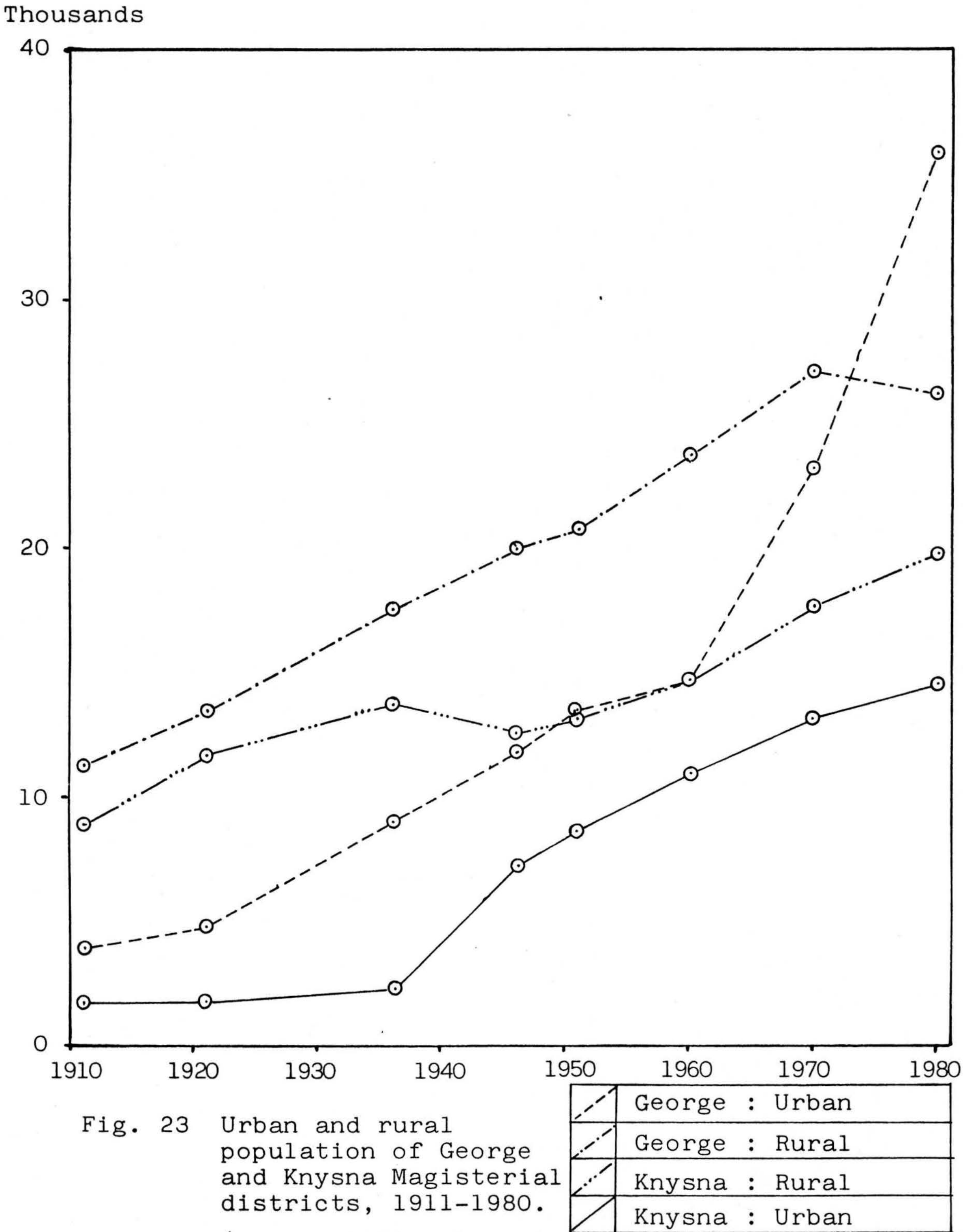

Fig. 23 Urban and rural population of George and Knysna Magisterial districts, 1911-1980.

(Tyson, 1971; Department of Statistics, 1982).

The Southern Cape's early history and resultant settlement pattern, its population structure and land utilisation pattern as discussed, are closely integrated with its transportation network over time. Road and railway connections are directly dependent on a variety of physical factors, such as the general ruggedness of the terrain brought about by the deeply incised river systems, the occurrence of marshes and lakes, the fairly impenetrable forest vegetation and, most important, the mountain range (Tyson, 1971, p. 16). As a result of this, land transport from the west only reached the George area towards the end of the 18th century, and the Outeniqua mountain barrier was only conquered at the turn of the 18th to the 19th century with the Cradock Kloof Pass and the Duivelskop Pass further east (Fig. 4). Road and rail access eastwards and northwards can to some extent be gauged from the following inception dates of the main transportation routes (Tyson, 1971, p. 16; Von Breitenbach, 1968, p. 37); Von Breitenbach, 1968(b)).

± 1800	Duivelskop Pass linking George via Bergplaas with the Langkloof;
1812	Cradock Kloof Pass linking George with the Karoo;
1847	Montagu Pass across the Outeniquas also linking George with the Karoo hinterland;
1862	Phantom Pass near Knysna, linking Knysna with the western plateau;
1862	Prince Alfred pass, linking Knysna with the Karoo hinterland;
1866	Robinson Pass, which links Mossel Bay more directly with the Little Karoo;

1882 Baynes Road linking George with Knysna;

1885 The Tsitsikamma Road linking Plettenberg Bay with the eastern flatlands;

1907 Railway-line between Mossel Bay and George;

1913 Railway-line opened across the Outeniqua range;

1951 The more modern Outeniqua Pass from George across the mountain range to the Little Karoo.

The impact of access on the forest location pattern appears important, since most of the marginal forest farmlands on either side of roads show distinct signs of forest removal or clearance.

This impact was broadly investigated in the Groenkop forest located east of George. The forest concerned appears on aerial photograph 8512, Flight 499/6 dated 1966 (Fig. 24) and is roughly located at 33°55' - 34°S by 22°30' - 22°35'E. Aerial photographs of 1957, 1959, 1966 and 1974 were studied to detect possible signs for forest clearance. During the 17 years concerned about 43 ha of forest was cleared, mainly for the following purposes:

a 25 metre wide strip for an electricity transmission line between George and Wilderness;

clearance for the building of a tar road between George and Saasveld;

clearance of forest for enlarging existing arable land;

clearance of forest for the erection of buildings.

Fig. 24 also shows the probable main directions of human impact and fynbos fire impact on forest margins in the past, as well as archaeological finds marked A and B. At A numerous stone tool implements were found alongside or in close proximity to the present western forest perimeter. They are tools of the Stellenbosch or Chelles-Acheul culture of the Earlier Stone Age (Kirkman, 1974). At B very old cave-dweller paintings and more recent Bushmen paintings, the former as yet undated, were discovered in a cavern. It can be assumed that the Bushmen would prefer the forest margin to the deep forest interior for purposes of safety, yet for the benefit of forest shelter, for purposes of the forest margin's richer food supply, both animal and vegetable, and for easy access and visibility outwards towards supposedly open grasslands. The present forest edge in the vicinity of B may therefore have been reasonably persistent for the past 300 - 500 years.

A further point of interest are the relatively open, deforested settlement perimeters. George, Knysna and Plettenberg Bay all feature larger forest patches only at distances in excess of five to ten kilometer radius. One would have expected the earlier timber depots to have been much closer to the productive forest perimeters. The impact of road access has however not been investigated yet.

4.5 The Economy of the Southern Cape

The Southern Cape's contribution to South Africa's gross domestic product was a mere 0,3% in 1960 (Tyson, 1971, p. 19).

In 1960 forestry, tourism and agriculture, in that order, formed the basis of the economy of the

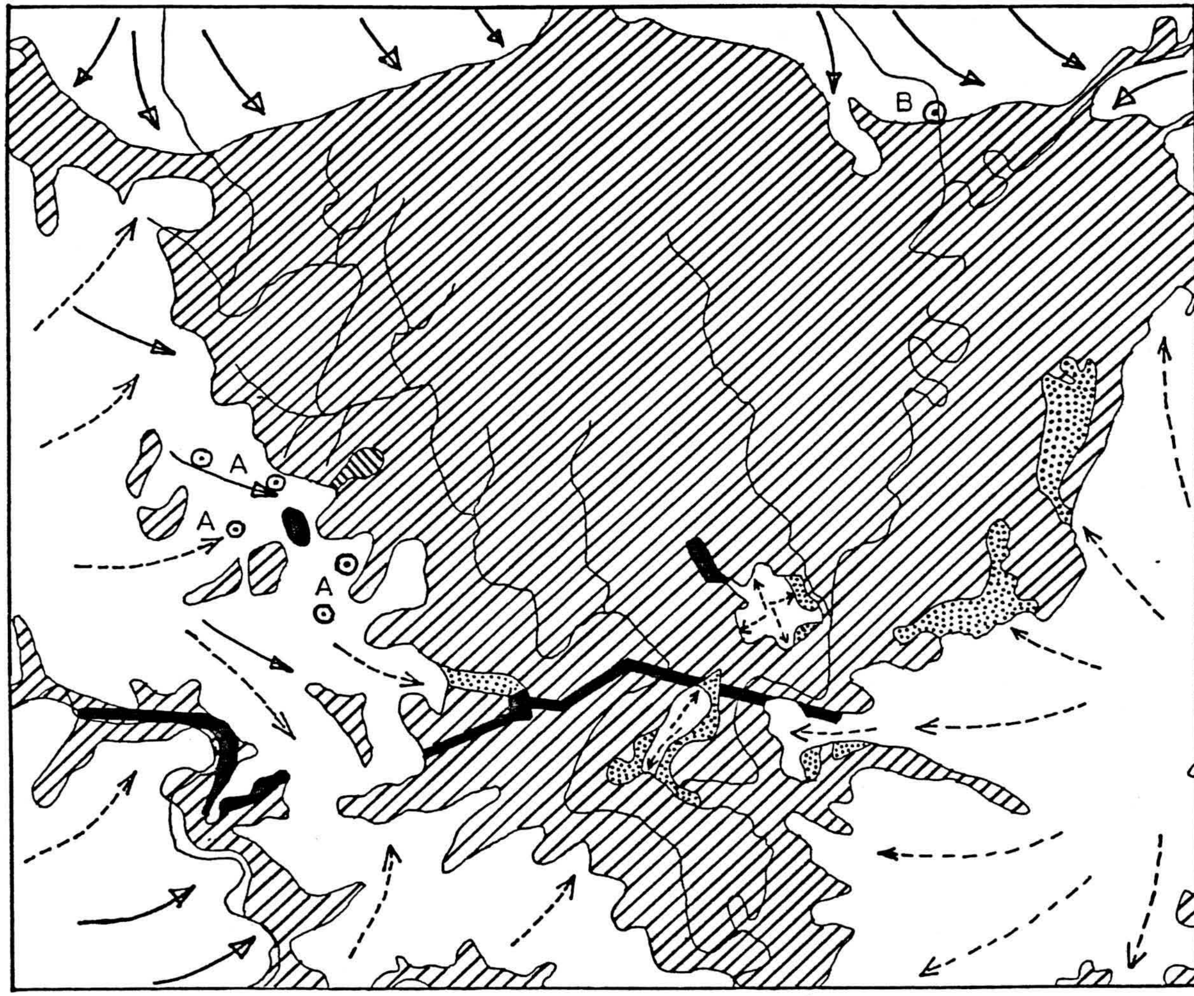

Fig. 24

The Groenkop indigenous forest: a local study of recent forest clearance.

N

0 500 1000 2000 m

	Direct human impact
	Fynbos fire impact
	Forest clearance: 1957 - 1966
	Forest clearance: 1967 - 1974
	Indigenous forests
	Forest rehabilitation
A	Stone implements
B	Aged rock paintings

George/Knysna area. More recent data still substantiates the above. Table 16 shows the Gross Geographic Product (G.G.P.) for the George and Knysna magisterial districts. It reveals a similar trend in both districts, in that agriculture, forestry and fisheries has declined in economic status from about 25% during 1968 to almost half of this, namely 12 - 13% of the G.G.P. seven years later in 1975. In fact, both have during the periods concerned revealed negative growth rates of between 1 - 1,5%. It is mainly banking and the building industry which show distinct positive growth. Projections made to 1990 indicate that agriculture, forestry and fisheries will yet further decline to about 10% G.G.P. (Department of Constitutional Development and Planning).

According to the Department of Constitutional Development and Planning (1983), rural agriculture and forestry activities in the Knysna district share equal status on the "labour-cost" market ("arbeidsvergoeding") at about 38% each of the total input, with fisheries lower down at 3%. In the George magisterial district agriculture dominates with 37% of the labour-cost market, with forestry trailing with 19%. Manufacturing (Table 16) must however be seen as closely allied with the processing of agricultural products and timber in both districts (Department of Constitutional Development and Planning, 1983; Tyson, 1971, p. 21), as must commerce, particularly in the Knysna district. Tyson (1971, pp. 19 - 23) provides a general description of the economy of the George/Knysna region, with special reference to tourism and agriculture.

4.6 Conclusion

In conclusion the following is aptly quoted from Moll (1981, pp. 2, 9):

TABLE 16 THE GROSS GEOGRAPHICAL PRODUCT FOR THE GEORGE AND KNYSNA DISTRICT FOR THE PERIOD 1968 TO 1975 EXPRESSED IN MILLION RAND (Rm) AND AS PERCENTAGE (Department of Constitutional Development and Planning, 1983)

DISTRICT	YEAR	Agriculture Forestry and Fisheries		Manufacturing		Commerce		Financial Services		Construction		Others
		Rm	%	Rm	%	Rm	%	Rm	%	Rm	%	%
George	1968	4,76	25,1	3,21	16,9	3,30	17,4	1,72	9,1	0,71	3,7	27,8
George	1970	4,47	19,5	4,24	18,5	4,00	17,5	2,45	10,7	1,01	4,4	29,4
George	1972	6,02	19,5	3,98	12,9	4,62	15,0	4,92	16,0	1,49	4,8	31,8
George	1975	6,68	13,4	4,47	9,0	8,70	17,5	8,44	16,9	7,25	14,6	28,6
Knysna	1968	2,37	24,6	1,57	16,3	2,24	23,2	0,67	7,0	0,40	4,1	24,8
Knysna	1970	2,07	18,9	1,95	17,8	2,51	23,0	0,90	8,2	0,44	4,0	28,1
Knysna	1972	2,69	16,9	1,68	10,5	2,86	17,9	1,85	11,6	0,96	6,0	37,1
Knysna	1975	2,93	11,8	3,65	14,7	4,56	18,4	3,16	12,7	3,79	15,3	27,1

"To date most research in indigenous forests has been limited to floristic studies with very little experimental work on plant or community physiology or process studies."

Knowledge "... is essentially observational ..." and "... being either of a descriptive nature, or more recently quantitive studies."

The previous chapters were intended as a brief but broad-based resumé of published data in answering the descriptive and observational, which in Chapter 1, were referred to as the "old" approach. It is by no means conclusive, but is intended to provide a "descriptive" picture of a forest which does not exist on its own and unrelated to its physical and human environment, but conversely, integrated into a wider ecosystem. The ensuing chapters are intended to analyse the location pattern of the indigenous forests through experimentation.

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CHAPTER 5

AN ANALYSIS OF THE LOCATION PATTERN OF THE INDIGENOUS FORESTS OF THE SOUTHERN CAPE : A REGIONAL STUDY

In the previous chapters the present forest location pattern was briefly described and answers to the questions "what?" and "where?" provided in broad outlines. The overriding question set in this chapter is: "How can this location pattern best be explained?" A variety of natural causative factors provide the basis for the setting of forests and these factors will have to be investigated as to their impact on the spatial location of the forests. Yet the present forest distribution pattern has also been influenced by the actions of man, and these cultural effects will have to be analysed and clarified as well. In a study of spatial variation patterns of tropical rain forests, Singh (1974, p. 19) also refers to the impact of these "... two broad groups, natural and cultural ..." as the main causes for differentiation in forest formation.

Two vital modes of approach had to be clarified namely, which specific factors are expected to best explain the forest location pattern and possible variations in such pattern, and secondly which specific methods will be best suited to explain the impact of these factors.

5.1 Basis for the Selection of Factors

The natural and human-cultural factors already referred to, affecting the forest location pattern, are obviously manifold and varied. Furthermore they frequently appear masked, meaning that the impact of any specific factor may not be readily evident, because of interaction of two or more factors on a specific site. From the outset the intention was not to incorporate all factors that possibly affect the distribution or variation pattern of the forests, but rather to select those that would best explain such pattern.

Wellington (1955, p. 303) with reference to the location of montane forest in general states:

> "The main causative factors are the heavy rains and the frequent mists brought in by the easterly winds, combined with the presence of slopes gentle enough to hold soil of sufficient depth for tree roots."

Haggett (1968, pp. 316 - 321), in a study of the location pattern of the natural forests in South-east Brazil, initially analised the impacts of a number of selected factors on a more localised basis. This was subsequently followed by an analysis of similar factors, though not the same, over a much larger region. In both cases Haggett's approach is based on the selection of factors on the assumption that they have an impact on what he terms "forest persistence". His basic problem therefore, appears not so much to involve an explanation of forest persistence, but to test the validity of the factors he assumed responsible therefore. For the local analysis of the Fortaleza Basin (100 km^2) Haggett selected terrain, soil, farm size and farm accessibility as factors influencing or having influenced 'forest persistence'.

For his regional analysis the considerably larger Sudeste region (62 000 km^2) served as basis, and here five indexes, namely terrain, settlement spacing, rural population density, forest density and land value served as factors. Particularly interesting is Haggett's argumentation for the selection of factors. While he was apparently guided by the most significant factors to have an impact on the forest location pattern in the Fortaleza study, the regional study appears to be based to a large extent on the availability of basic data and not so much on the importance of the factors themselves.

Dumont (1964, pp. 18 - 20) stresses the importance of rainfall, insolation (aspect), slope, geology and agricultural use as factors affecting the spatial location of 'rain forest' in Zaïre.

Hall and Swaine (1976, p. 949), in respect of the forests of Ghana, conclude that a close correlation exists between forest types and the factors rainfall and geological formations, as well as altitude, topography and fires.

Tyson (1971, p. 19) concludes that the present forest distribution pattern of the Southern Cape is to a large extent explained by the factors aspect, precipitation, degree of slope, former inaccessibility, 19th century "squatter" agriculture and fires.

Guided to a certain degree by the literature cited above, particularly Haggett (1968), descriptions of the Southern Cape forests referred to in the previous chapter, and by practical inference, the following factors were singled out for the reasons provided as likely the most significant in explaining the local forest location pattern. It is the intention to substantiate such choice by full analysis in the ensuing sections.

5.1.1 Topographical or Terrain Types

The terminology 'terrain types' refers to general relief configuration systems of a particular area and may include, as Buys (1971, p. 4.12) expresses it, such physiographic elements as local relief, degree of flatland or slope, ridge lines in the mountains, ravines, valley floors and the physical nature of the exposed surface. In the Southern Cape context Von Breitenbach (1968, p. 69) refers to four principal topographical zones, the littoral, lower and upper plateaus and the mountains, though the mountain slopes and plateaus are deeply intersected by ravines, valleys and gorges as well. Forests occur mainly along the flatland upper plateau in the Tsitsikamma, along the plains and lower Outeniqua foothills in the Knysna forest heartland region, while a distinct locational setting towards steeper slopes and away from the plains is noticeably westwards, both along the steeper coastline south of George and the Outeniqua slopes north and west of George. Forest however also occurs in the deeper river incisions disecting the plains. The term "terrain types" will in the Southern Cape context therefore have to take into account such parameters as degree of slope (from flatland to steep mountains) for the broader topographical patterns, and ruggedness of terrain to account for more localised deviations from such broader patterns. The term "ruggedness" has been associated with drainage density and relative relief (Singh, 1971, p. 15).

5.1.2 Rainfall

Of the main parameters of climate, namely precipitation, temperature and wind, precipitation is expected to reveal the most direct correlation with forest distribution (Hall and Swaine, 1976, p. 949). Generally speaking rainfall in the Southern Cape increases from west to east and from the coast-line to the mountain slopes (Von Breitenbach, 1968, p. 84; Fig. 13). Von Breitenbach (1968, p. 84) however also states that the forest distribution appears better represented in the "less extreme zones", implying the medium-moist and not the very wet nor dry zones.

5.1.3 Altitude

The major vegetation belts are climatically strongly influenced by the interrelationship between latitude and altitude. This is particularly noticeable with the distribution of tropical and subtropical forest types (Richards, 1952, pp. 358 - 372; Banerjee, 1977, p. 177; Stern and Roche, 1974, p. 208; Hall and Swaine, 1976, p. 941). The climatic parameter involved with altitude is temperature (or insolation). At higher latitudes subtropical forest location patterns are expected to react more sharply to altitudinal differences than at lower latitudes. It is therefore expected that the Southern Cape forest location pattern, at a constant latitude of 34° South, will reveal a fairly strong correlation with variation in height above sea level, although other climatic parameters, such as temperature/insolation mentioned in par. 5.1.4 below, and the precipitation pattern, may mask such correlationary effects or trends.

5.1.4 Aspect

Aspect is also a parameter of climate, involving both temperature, based mainly on exposure to insolation, and precipitation, based mainly on exposure to the main rain-bearing winds. Hutchins (1893, p. 127) probably over-emphasised the importance of aspect, when he stated:

"There is historic evidence that most, if not all, the ranges of mountains facing the sea-board, as well as the higher mountains for hundreds of miles inland, were at one time clothed with the beautiful timber forests of which we have now remains at Knysna."

It is nevertheless to be expected that cooler, moister southerly to easterly facing slopes will be more densely forested than the warmer, drier northerly to westerly aspects.

5.1.5 Geology and Soils

Singh (1974, p. 19) states that, among the natural factors responsible for variation in tropical forest variation, climatic factors are relatively uniform while topography and soil are responsible for most variation. Symons (1968, p. 21) however states that the characteristics of soil are largely the product of present and past climates and the vegetation that has flourished thereon. It would therefore appear that an explanation of variation in forest patterns should not so much be sought in soils because soil forming processes and natural vegetation cover are too directly interdependent on each other. Wellington (1955, p. 11) and Phillips (1931, p. 17) stress the importance of underlying rock instead. The parent rock, source of the mineral soil, is obviously equally directly associated with soil formation, particularly because of the physical, textural characteristics and nutrient-fertility attributes it imparts on soil. The study of geological formations and resultant soils on forest cover should therefore be attempted, on the hypothesis that there is a positive correlation between underlying rock characteristics and variation in the forest location pattern.

5.1.6 Accessibility

The more easily accessible forests, located on the plains and along the lower foothills, are likely to have been denuded more by the acts of man than the more distant and inaccessible forests located in river valleys and mountain ravines. Man's acts include direct timber exploitation, grazing, hunting and exposing land for cultivation. However man also used an important tool for attaining access: the use of fire. Fire is however also a natural factor restricting forest expansion, and can therefore not be attributed as such to human accessibility alone. It is arguable that "human accessibility", which can be linked to the settlement history of the Southern Cape, should reveal a direct impact, though inversely related, on the forest distribution pattern, i.e. the more accessible, the less forest. Similar arguments were used by Haggett (1968, p. 316) although he used the term "farm access".

5.1.7 Population

Closely associated with "human" accessibility, this human factor is based on the assumption that there exist an inverse relationship between the "rural" population of the Southern Cape and forest area, i.e. the denser the rural population, the less the forest area.

5.1.8 Summary

This discussion is based on the postulation that the present location pattern of the Southern Cape indigenous forests and its spatial variation, can be suitably explained by the impact of some or all of the seven factors selected above. The relationship or impact is not always a direct one and may therefore be inverse. The factors concerned are:

Topographical, thereby referring to terrain types based on the relief attributes of degree of slope and parameters of ruggedness;

climatic, thereby referring to precipitation, altitude and aspect;

geomorphological, particularly the effect of geological material;

human-cultural, with special reference to human access and rural population.

5.2 Method of Analysis

Prior to data collection and to further analysis of such data, it is essential to clarify the method of analysis to be used. The following four essentials are required:

Stating the problem:

This requirement can summarily be formulated in hypothetical form as: It is thought possible to explain the spatial variation pattern of the Southern Cape indigenous forests by modern experimental designs;

choosing the specific mathematical models to be used;

determining the essential variables;

selecting a sampling design to suite the model.

To be more specific, it is assumed that the factors terrain types, rainfall, geological formation aspect, altitude, accessibility and rural population will satisfactorily explain variance in the location pattern of the Southern Cape indigenous forests. The more specific problem is therefore what formal mathematical model to choose to test the validity of this assumption and what method of data analysis to choose within the design to express each of the factors concerned satisfactorily.

Concerning the mathematical model to be used, brief reference has already been made to the model of Haggett (1968) in his study of the Fortaleza Basin of Brazil. He used the Yates 2^n factorial design based on variance analysis as described by Davies (1967, pp. 274 - 281). In his regional analysis of the much larger Sudeste, Haggett applied multiple regression analysis. For the Southern Cape the choice of models lay essentially between these two approaches. Each alternative had its distinctive problems particularly with regard to the accommodation of a large number of variables.

The regression analysis design is normally well suited to accommodate a large number of variables, although it requires the expression of variables at a reasonably large number of levels in order to become significantly valid. This would therefore result in very complex data collection for each of the variables concerned. More problematic, though, is the requirement to express the factors in statistically acceptable terms, e.g. geological formations are not directly expressible in quantitive-measurable terms. In variance analysis, variables need only be expressed and tested at two levels (referring to the 2^n model). Since most of the variables, aspect and accessibility in particular, appeared rather difficult to be expressed at a large number of levels, unless one would go to extreme sampling accuracies, the variance analysis was automatically favoured.

A second reason why the variance analysis was favoured, was the intention to use the statistical data for factorial combination designs thereafter for purposes of modelling potential indigenous forest area.

In order to compensate to some degree for possible loss in sampling accuracy, the basic model was intended to be deterministic from the outset, i.e. with no sampling. The population size was also regarded small enough to allow for all factors to be located and measured over the whole study area. This meant that, since performance was to be fully described, there would be no statistical estimation nor random components, since no sampling was envisaged. Factorial performance is in this case normally described within contiguous quadrats which cover the whole study area (Orlóci, 1975, pp. 4 - 5).

The next problem was accommodation of such a large number of factors, i.e. possibly seven or even more within the model. The decision to resort to a complete enumeration with no sampling, was also associated with this problem. With no sampling error to contend with, it was felt that, should the factorial grouping become too mazed and thereby too difficult to control, it would be possible to split them into two tangible groups. Such steps would obviously tend to be open to a measure of manipulation and would have to be very carefully controlled.

One aspect is hereby stated clearly, and that is that the effect of the variables mentioned, would have to be investigated both on a regional and on a more local level. Haggett (1968) dealt with the local study of the Fortaleza Basin first and followed this up with an analysis of the larger Sudeste region. In the Southern Cape context, it was intuitively assumed that an explanation of forest location patterns lay not so much on regional but on local levels. An indicator for this assumption lay in the fairly evident trend of a higher forest cover on level terrain in the Tsitsikamma than west of George, where only the steeper slopes appear forested.

5.3 Representation of Factors and Their Statistical Significance

Concerning the choice and representation of variables, Orlóci (1975, p. 6) stresses that variables must be meaningful in terms of the formulation in the mathematical model, sensitive to changes in the controlling factors, but simultaneously sufficiently buffered against minor influences that could obscure important trends in their variation; and that consideration be given to a combination of different criteria in any "a priori" evaluation of the potential applicability of the variables, meaning that the variables should possess such qualities as additivity, commensurability and relativity.

In this connection a combination of different criteria for commensurability or standardisation point to two possible approaches, one of a direct, the other of an indirect relationship. The indirect relationship is based on a combination of different criteria, which are expressed as indexes, and where any specific factor tends to be obscured or hidden, e.g. the Forest Density Index of Haggett (1968, p. 34) which he represents by a combination of annual rainfall (in inches) and the weight of vegetation (in lbs. per acre). The direct relationship refers to a variable being directly recognisable as such, e.g. a 400 - 500 mm of rainfall region. For purposes of a deterministic approach the direct relationship was favoured, also for the further use of statistical results for forest location models later on. Indirect indexes would have been prohibitive in this respect.

It was further decided to test the variance of selected factors at two levels according to Yates' 2^n method for the final factorial analysis, but initially at preferably more levels to determine the statistical significance of each factor separately where possible.

Having decided upon the basic model and the variables to be used in the factorial analysis, the methods of representing each of these variables had to be resolved:

5.3.1 Terrain Types

The term terrain is associated with both gradient and slope. Though various methods have been devised to represent slope and gradient, such as Wentworth, Smith, Raisz and Henry (Monkhouse and Wilkinson, 1961, pp. 77 - 82), Wentworth's method of average slope determination based on an east-west and north-south grid over a contour map and therein counting the number of contour crossings, was considered the most appropriate and suitable. Wentworth repeated this procedure by using an oblique grid over the same area and thereafter using a formula to arrive at an average slope in terms of the tangent of the average angle of slope. This method was also used by Tait (1969, p. 480) in gradient studies in the Ciskei.

Buys (1971, pp. 4.15 - 4.17) describes a method whereby terrain types are determined by local relief (number of contours within a unit square) and average slope. Both Wentworth's method and Buys's method were tested and it was decided to use a modified version of Buys's method. Buys's empirical rule for choice of the optimal size of a unit grid is derived as follows:

(a) Determine the base distance in terms of the map scale, the contour interval and the average slope for the whole region, in this case:

$$\text{Base Distance} = \frac{\text{Contour Interval x 100}}{\text{Average Slope}}$$

(b) Multiply the above by two to represent the diagonal of the unit, square this figure, divide by two and determine the square root.

(c) Convert this figure to obtain the approximate length of the unit side, in latitude units. Choose the nearest suitable size for a unit grid and apply.

Buys's method for the choice of a unit square was first applied per se on the 1 : 250 000 Topo-cadastral map series with 150 m contours and tested. His choice of a unit square of 1,25 min. x 1,25 min. was found to be too large to effectively discern between particularly level terrain and the lower foothills. The unit square was therefore reduced to one minute by one minute and this reduced the number of contours per unit square sufficiently to reveal the terrain patterns concerned.

It was further felt, after experimentation, that the average slope divider in (a) above served no practical purpose in distinguishing markedly between final terrain types, and it was therefore abandoned. The results of this treatment strongly emphasise local relief and average slope on a regional basis, however such local parameters of ruggedness as ridge lines and river valleys, remained fairly indistinct. It was therefore decided to draw two "terrain type" maps, one based on the 1 : 250 000 topo-cadastral map with 150 m contours and which emphasises the regional relief pattern, and the other on the 1 : 250 000 topographical map, which features 50 m contours and emphasises more local relief details. These two terrain types were not intended for comparison, but for one to supplement the other.

5.3.1.1 Macro-Terrain Type

A map featuring the outlines of the study area was drawn to a scale of 1 : 250 000 and covered with a grid of one minute by one minute. This map was superimposed on the 1 : 250 000 topo-cadastral map and the number of contours in each grid unit were counted and recorded for the relief types shown in Table 17, conveniently termed "macro-terrain types".

This Basic Data Map, which is not directly reproduced here, was thereupon superimposed on the Forest Distribution Map (Fig. 6) drawn to the scale of 1 : 250 000 and the Forest Distribution Control Map (Fig. 7 represents portion thereof).

The total land area for each of the terrain types featuring on Table 17 as well as the total forest area within each type were enumerated (Table 18). For the purpose of absolute control over area, each longitude column (one minute) was accorded a fixed

TABLE 17 MACRO-TERRAIN TYPES: SOUTHERN CAPE

NO. OF CONTOURS PER GRID-UNIT	CALCULATED AVERAGE MAXIMUM GRADIENT	AVERAGE GRADIENT	TERRAIN TYPE*
0 and 1 (open)	5,4°	0 - 5°	Level
1 (closed or doubled) and 2	10,8°	5 - 11°	Gently sloping
3	15,9°	11 - 16°	Moderate foot-hills
4	20,8°	16 - 21°	Mountains
5 and more	25,4°	> 21°	Very steep slopes

* (after Moll et al, 1976, p. 46 and Symons, 1968, p. 55)

TABLE 18 MACRO-TERRAIN TYPES : INDIGENOUS FOREST COVER

TERRAIN TYPE	TOTAL LAND AREA		FOREST AREA		PERCENTAGE FOREST COVER
	Ha	%	Ha	%	
Level	187 747	41,9	34 786	52,9	18,53
Gently sloping	162 856	36,4	24 167	36,8	14,84
Moderate foothills	65 571	14,7	4 732	7,2	7,22
Mountains	25 884	5,8	1 775	2,7	6,86
Very steep slopes	5 521	1,2	253	0,4	4,58
TOTALS	447 579	100,0	65 713	100,0	14,68 average

"number of squares of forest cover" (Fig. 7). This control was also used to control areal differentiation in all the other variables tested. Fig. 25 reveals the five terrain types more or less succeeding each other from the coast-line level terrain to the steep inland mountains.

Of the indigenous forests 89,7% are located from 0 - 11°, which in turn represents 78,3% of the total land area (Table 18). There is a distinct tendency of a reduction in forest cover with increasing steepness of terrain. The plains west of the Kaaimansriver are however virtually unafforested, while certain coastal plains between Knysna and George are only sparsely forested. Fig. 25 indicates that the Outeniqua mountain range is not uniformly steep. This is particularly noticeable north of Knysna.

Linear regression analysis was used to test the significance (t - test) of the relationship between each variable and forest cover (Table 19 and Fig. 26).

Percentage data in the lower extremes of the range (0 to 30%) are "notoriously" difficult to be accommodated in statistical analysis of this kind (Haggett, 1968, p. 316; Fisher and Yates, 1963, p. 15). The percentage forest cover was therefore transformed to angular values with the aid of Standard Conversion Tables. These angular values were used to test correlation trends (Fig. 26).

The regression line (Fig. 26) and above findings clearly indicate that there exists a strong inverse correlation between local relief and forest cover.

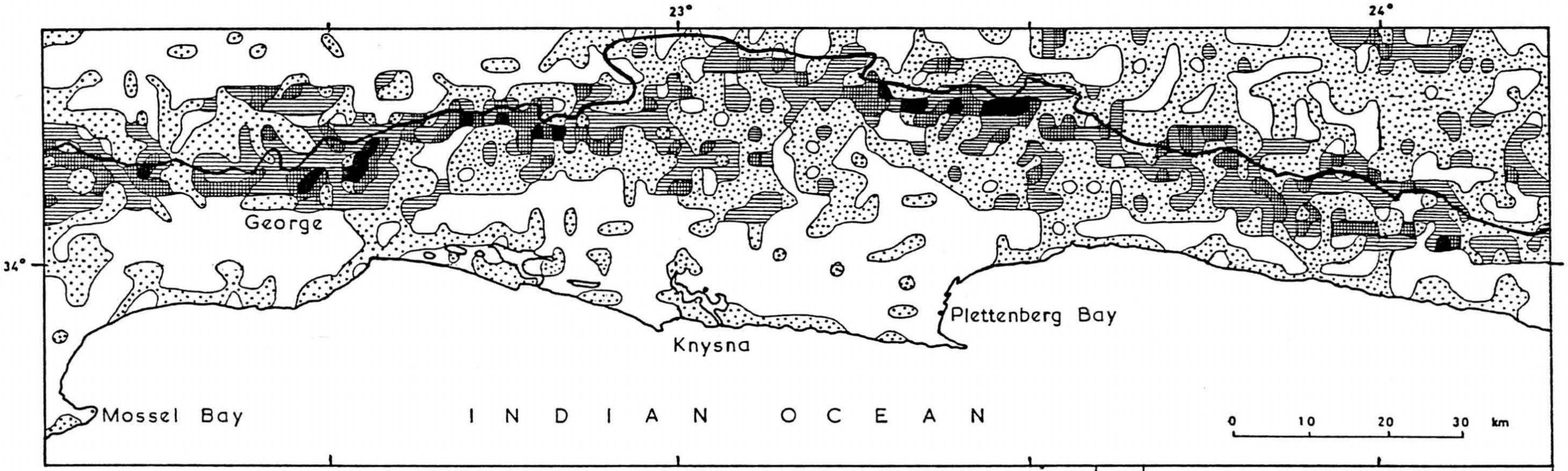


Fig. 25 Macro-terrain types of the Southern Cape.

Level terrain	5°
Gently sloping	5 - 11°
Moderate foothills	11 - 16°
Mountains	16 - 21°
Very steep	21°

TABLE 19 MACRO-TERRAIN TYPES: SIMPLE REGRESSION ANALYSIS

X-VARIABLE (AVERAGE SLOPE)	Y-VARIABLE (CONVERSION)	
	Percentage	Angular Transformation
1. 2,5°	18,53	25,50
2. 8,0	14,84	22,66
3. 13,5	7,22	15,57
4. 18,5	6,86	15,18
5. 23,07	4,58	12,34
Significance test:	r - value = - 0,9687	
	t - value = - 6,7602 (> 99%)	

5.3.1.2 Micro-Terrain Type

The purpose with this relief type was on the one hand to reveal the effects on forest location of the rugged nature of the river incisions along the plains and foothill zone, and on the other hand the interesting occurrance of forests up the steeper river gorges into steeper mountain terrain. Singh (1974, p. 18) discusses the importance of discerning between macro- and micro-patterns in spatial variation in tropical rain forests, with micro-patterns providing more detail. From the 1 : 250 000 topographical mapping series, which feature 50 m contour intervals, and based on Buys's (1971) empirical rule for the choice of a calculated unit block, a grid-unit of 0,5 minutes by 0,5 minutes (actually calculated as 0,464 min. x 0,464 min.) was decided upon.

Basically the same mapping procedure was followed as with the macro-terrain type, with the difference that the micro-terrain study represented extremely

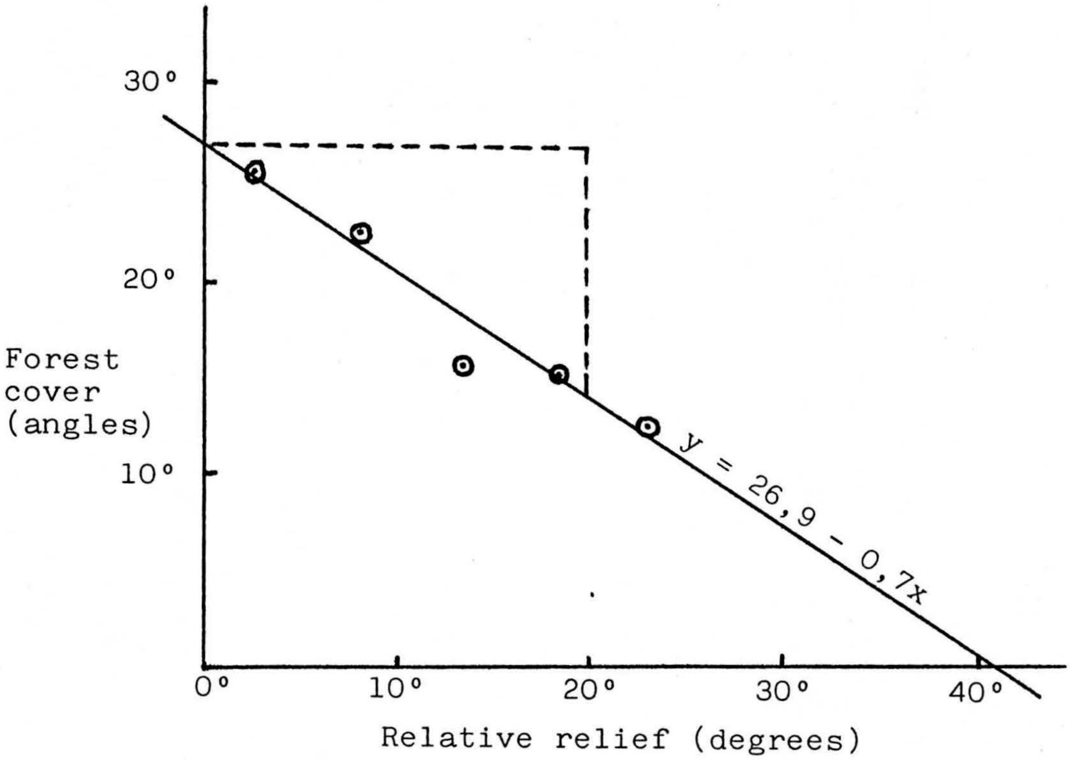


Fig. 26 Macro-terrain types: linear regression analysis.

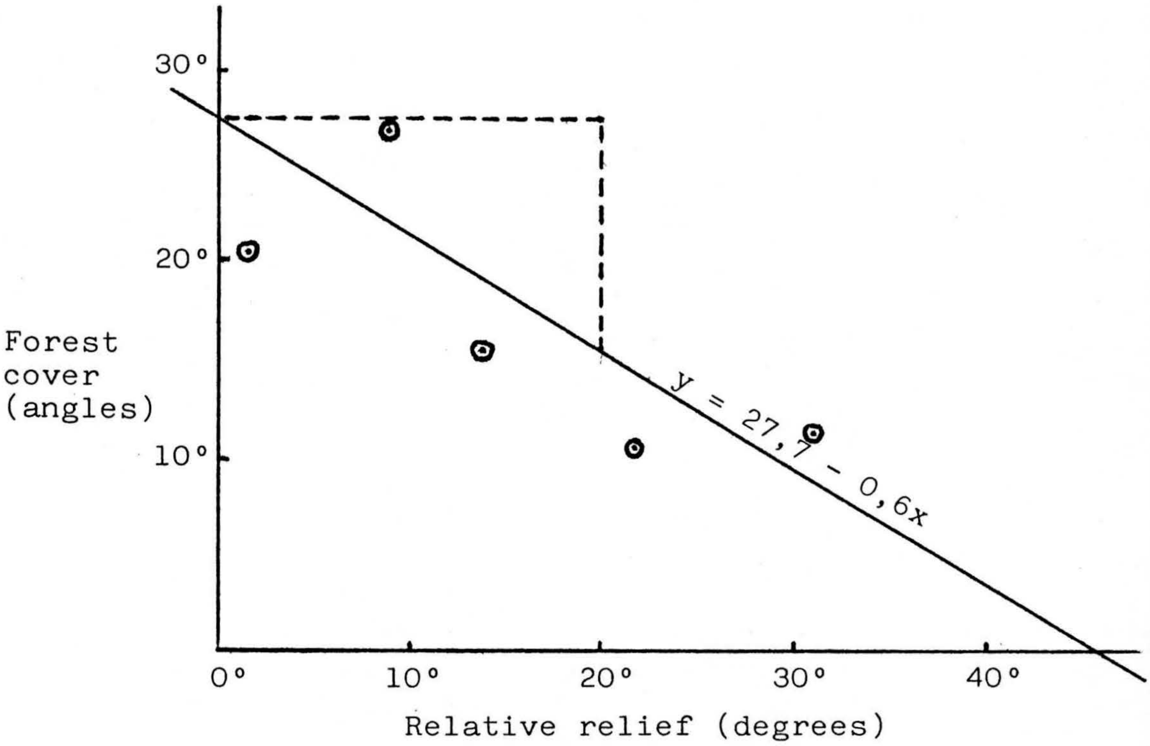


Fig. 27 Micro-terrain types: linear regression analysis.

fine and detailed work, involving the investigation of contour lines within about 6 350 unit squares, four times as many as the larger squares in the macro-terrain study. The number of contour lines were again counted in each unit square and the separate micro-terrain types distinguished feature in Table 20.

It should be noted that the macro- and micro-terrain types differ in their respective average gradients, e.g. level is 0 - 5° in macro-terrain but 0 - 3,5° in micro-terrain. This was done deliberately to test the validity of the statistical tests as well as to make provision for possible hidden variation. The detailed micro-terrain grid map was superimposed on the Forest Distribution and the Forest Distribution Control Maps in order to determine the total land area and the indigenous forest cover within each terrain type. This information is provided in Table 21.

TABLE 20 MICRO-TERRAIN TYPES : SOUTHERN CAPE

NUMBER OF CONTOURS PER GRID-UNIT	CALCULATED AVERAGE MAXIMUM GRADIENT	AVERAGE GRADIENT (SLOPE)	TERRAIN TYPE
0 and 1	3,5°	0 - 3,5°	Level
2	7,0°	3,5 - 7,0°	Gentle slopes and rugged drainage
3	10,5°	7,0 - 10,5°	Moderate slopes
4 and 5	17,2°	10,5 - 17,2°	Foothills
6, 7 and 8	26,4°	17,2 - 26,4°	Mountains
9 and above	> 26,4°	> 26,4°	Very steep slopes

A micro-terrain type map could not be reproduced intelligibly, because of the maze of diversified terrain type grid-units.

TABLE 21 MICRO-TERRAIN TYPES: INDIGENOUS FOREST COVER

TERRAIN TYPE	TOTAL LAND AREA		FOREST AREA		PERCENTAGE FOREST COVER
	Ha	%	Ha	%	
Level	135 448	30,3	16 393	25,0	12,10
Gentle slopes and rugged drainage	102 942	23,0	28 524	43,5	27,71
Moderate slopes	60 733	13,6	12 431	18,9	20,47
Foothills	90 031	20,1	6 337	9,6	7,04
Mountains	52 500	11,7	1 803	2,7	3,43
Very steep slopes	5 925	1,3	225	0,3	3,80
TOTALS	447 579	100,0	65 713	100,0	14,68 average

Of the indigenous forests 87,4% occur on plains to moderate slopes, i.e. gradients from 0 - 10,5° (Table 21). This figure compares favourably with the 89,7% of forests on 0 - 11° in the macro-terrain type (Table 18). What is however highly significant is the comparatively low percentage forest cover of 12,10% of the level terrain type (0 - 3,5° average slope in Table 21) in comparison to the forest cover of 18,53% of the level macro-terrain type (0 - 5°) (Table 18).

The regression line (Fig. 27) and results of Table 22 reveal that the effect of local relief on forest cover is statistically insignificant. It was originally thought that this was due to the effect of the sparsely forested plains, but even with the application of the curvilinear regression formula ($Y = A + BX + CX^2$), the r-value remains virtually the same (r-value = - 0,7759). This treatment clearly reveals the necessity for testing terrain types at more levels for statistical significance. As will be seen the statistical insignificance of the correlation between micro-terrain and forest cover, did not invalidate this factor for use in the variance analysis.

TABLE 22 MICRO-TERRAIN TYPES: SIMPLE REGRESSION ANALYSIS

X-VARIABLE (AVERAGE SLOPE)	Y-VARIABLE (CONVERSION)	
	Percentage	Angular Transformation
1. 1,75	12,10	20,36
2. 5,25	27,71	31,76
3. 8,75	20,47	26,89
4. 13,85	7,04	15,38
5. 21,80	3,43	10,68
6. 31,00	3,80	11,24

r-value = - 0,7746

t-value = - 2,4493 (< 95%)

5.3.2 Rainfall

The second factor to be analysed is rainfall. The Rainfall Distribution Map (Fig. 13) is based on records from 69 rainfall recording stations. This map features simple isohyets at 100 mm intervals and was used as base map for investigating the effects of rainfall on forest distribution. The Rainfall Map (Fig. 13, drawn to a scale of 1 : 250 000) was superimposed on the Forest Distribution Map (Fig. 6, drawn to the same scale of 1 : 250 000) and the total land area, and thereafter the total forest area was independently determined for each of 100 mm rainfall intervals (Table 23), the Forest Distribution Control Map (Fig. 7) being used to control the one-minute longitudinal columns.

TABLE 23 THE EFFECT OF RAINFALL ON FOREST COVER

RAINFALL TYPES (mm)	TOTAL LAND AREA		FOREST AREA		PERCENTAGE FOREST COVER
	Ha	%	Ha	%	
< 500	13 911	3,1	0	0	0
501 - 600	28 629	6,4	106	0,2	0,37
601 - 700	74 194	16,6	1 457	2,2	1,96
701 - 800	106 451	23,8	14 160	21,5	13,30
801 - 900	95 161	21,3	14 610	22,2	15,35
901 - 1000	50 806	11,3	11 760	17,9	23,15
1 001 - 1 100	47 782	10,7	14 260	21,7	29,84
> 1 100	30 645	6,8	9 360	14,3	30,54
TOTALS	447 579	100,0	65 713	100,0	14,68 average

The above statistics imply that rainfall below 700 mm inhibits tree growth and forest development. The meagre 2,4% of forests actually growing in the below-700 mm rainfall range, covering 26,1% of the study area, are mainly encountered along sheltered and moist river stream beds. The overall trend is obvious, with an increase in forest cover with increase in rainfall. This trend is substantiated by the simple regression analysis and test for significance depicted in Table 24 and Fig. 28, which reveal a very strong correlation between rainfall and forest cover.

Needless to mention, a strong relation is expected to exist between rainfall and the south-facing steeper slopes, but the interrelationship between factors was to be separately tested later in the factorial analysis. It should be noted that the rainfall in the steeper mountains may have been underrated, although Richards (1952, p. 358) in a study of Central Africa, intimates an initial increase in rainfall with rise in altitude at lower levels, followed by a noted decrease at higher altitudes.

5.3.3 Geological Formations

"The effects of geology can rarely be ignored in geographical problems ..." (Wellington, 1955, p. 11). Haggett (1968, p. 316) used soil as factor in variance analysis for his study of Brazil forests and in the two-level treatment he compared "mica-schist soils" with "other soils", based on the observation that the former supported a larger forest cover than the latter. The term "mica-schist" is however also a distinct reference to geological origin rather than soil formation. Hall and Swaine (1976, p. 949) mention the importance of the effects of underlying rock on forest formation in Ghana. It was decided to statistically test the impact of geological formation on the forest location pattern, rather than the effect of soil cover, mainly because the latter is largely dependent on geological parent material, on climate and on the vegetation it supports. Six geological divisions are recognised (Fig. 8) and the total Southern Cape study area as well as the total forest area was again determined for each of these divisions (Table 25) with the aid of the two forest distribution maps already referred to under terrain types and rainfall.

The impact of geological formations on the forest location pattern is not readily forthcoming from the results of Table 25. Other factors, such as rainfall and degree of slope, prove to be more dominant, yet the purpose here is to single out geological impact.

The very low percentage forest cover of 3,28% on the Cape Granites appears rather misleading. In fact,

TABLE 24 RAINFALL : SIMPLE REGRESSION ANALYSIS

X-VARIABLE	Y-VARIABLE (CONVERSION)	
	Percentage	Angular Transformation
1. 450 mm	0,00	0,00
2. 550	0,37	3,50
3. 650	1,96	8,04
4. 750	13,30	21,39
5. 850	15,35	23,07
6. 950	23,15	28,76
7. 1 050	29,84	33,12
8. 1 150	30,54	33,54

r-value = 0,9750
t-value = 10,7434 (> 99,9%)

TABLE 25 THE EFFECT OF GEOLOGICAL PARENT MATERIAL ON FOREST COVER

GEOLOGICAL FORMATION	TOTAL LAND AREA		FOREST AREA		% FOREST COVER
	Ha	%	Ha	%	
Cape Granite	34 354	7,7	1 127	1,7	3,28
Superficial deposits	29 879	6,7	1 408	2,1	4,71
Enon beds	20 766	4,6	1 690	2,6	8,14
Table Mountain sandstone	299 193	66,8	47 883	72,9	16,00
Bokkeveld shales	24 194	5,4	5 155	7,8	21,31
Malmesbury shales	39 193	8,8	8 450	12,9	21,56
TOTALS	447 579	100,0	65 713	100,0	14,68 average

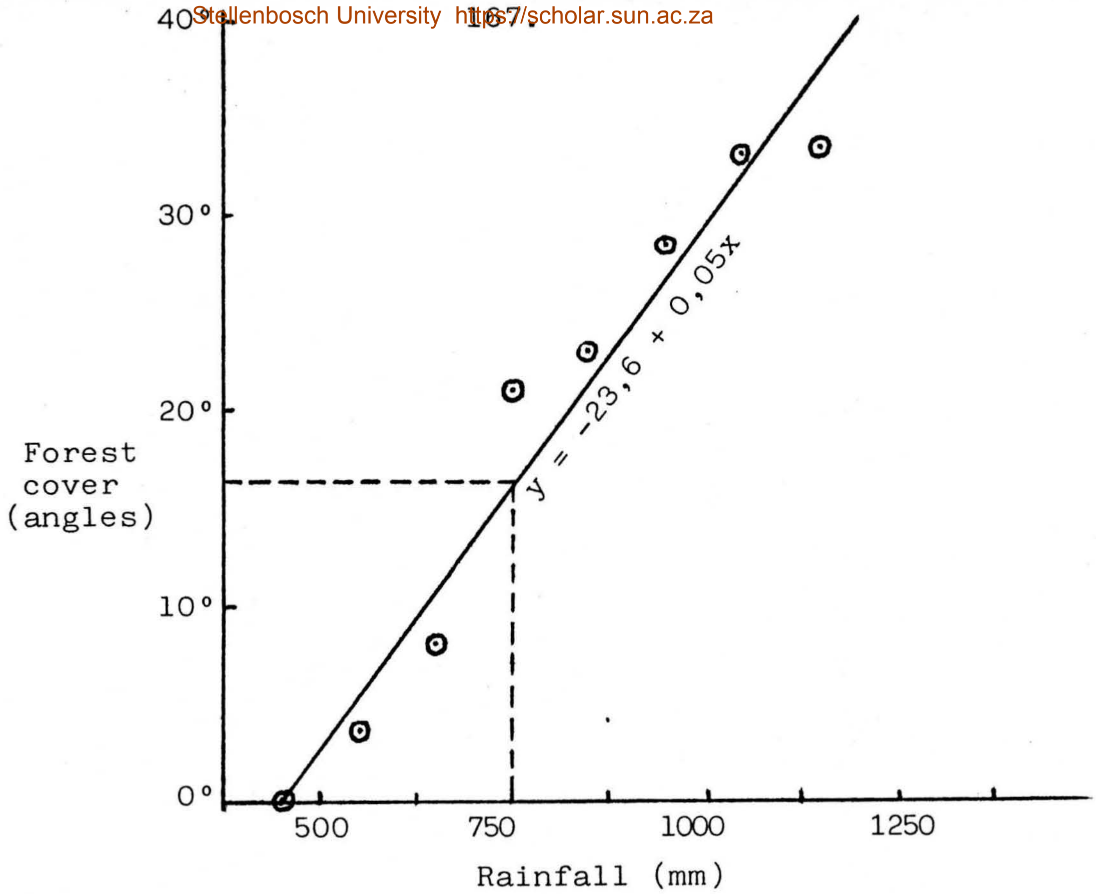


Fig. 28 Rainfall: linear regression analysis.

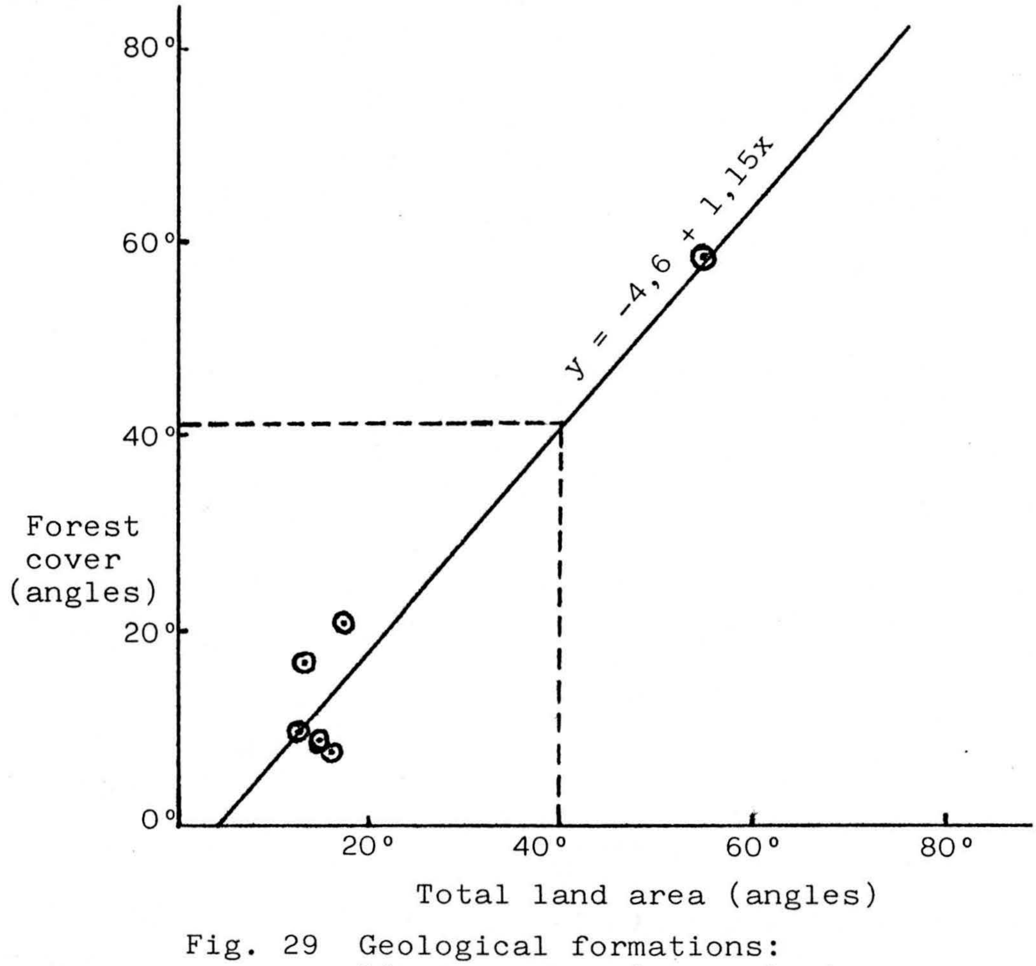


Fig. 29 Geological formations: linear regression analysis.

only the smaller eastern outcrop between George and Knysna (Fig. 8) features notable forest cover. This eastern Cape Granite outcrop receives a rainfall of between 700 to 900 mm, while the western outcrop on average receives a much lower rainfall, between 500 and 900 mm. The "eastern" Granites were separately evaluated on the base maps. This outcrop was found to be 6 700 ha in total land area (of the total of 34 354 ha on Table 25), with a forest area of 1 044 ha (of the total of 1 127 ha on Table 25). This means that the eastern outcrop features a 15,6% forest cover, while the larger western outcrop only features a 0,3% forest cover.

Table Mountain Sandstone definitely dominates both the total surface and forested areas, yet the effect of the steeper mountain slopes as well as that of marginal rainfall does appear to restrict forest growth. The relatively low percentage cover on loose Superficial Deposits and the coarser Enon Beds as well as the relatively higher forest cover on the more fertile loam soils of the Bokkeveld and Malmesbury shales are however more revealing.

The representation of geological formations into sequence as independent variables provided some difficulty. It was thought feasible to provide a geological index based on the soil texture, more specifically the sand fraction, provided of course that the soils concerned were by and large residual. However in the absence of sufficient textural soil data for the study area, this method was not pursued further.

The significance test conducted in this case is based on the forest population as a dependent variable of the total surface area (Table 26 and Fig. 29).

TABLE 26 GEOLOGICAL FORMATIONS : SIMPLE REGRESSION ANALYSIS

FOREST COVER (ha)		TOTAL LAND COVER (ha)	
X-variable	Angles	Y-variable	Angles
1. 1 127	(7,52)	34 354	(16,08)
2. 1 408	(8,42)	29 879	(14,97)
3. 1 690	(9,23)	20 766	(12,44)
4. 47 883	(58,61)	299 193	(54,85)
5. 5 155	(16,26)	24 194	(13,45)
6. 8 450	(21,01)	39 193	(17,21)
r-value = 0,9903 t-value = 14,2592 (> 99%)			

The high significance level (t-value) is obviously strongly influenced by the dominant Table Mountain Sandstone. Fig. 29 represents a linear regression, in which the direct land cover figures of Table 26 were changed to percentages of their respective totals, and thereafter transformed to degrees. These figures appear in brackets on Table 26. As a result thereof the coefficient of correlation factor for Fig. 29, namely r = 0,9677, differs somewhat from that in Table 26, namely r = 0,9903. In order to reveal the role played by Table Mountain sandstone (TMS), the treatment (Fig. 29) was repeated by disregarding TMS. The coefficient of correlation (r = 0,3543) in this case proved to be entirely insignificant.

5.3.4 Aspect

Aspect as an environmental factor, has not been frequently used in geographical research (Tait, 1969, p. 479). Tait used streams and watershed ridge lines as boundaries and classified slope direction (aspect) into six categories each 60°, namely S to WSW, WSW to

WNW, WNW to N, N to ENE, ENE to ESE and from ESE back to S. This method was tested and found to be a good proposition for larger scale topographical maps, such as 1 : 50 000 series, which Tait in fact used. For the larger Southern Cape study area the 1 : 250 000 Topographical Series, which feature 50 m contour intervals, was used. The unit-grid of 0,5 minutes x 0,5 minutes, which had been used for micro-terrain patterns, was also used for determining the following dominant slope directions within each unit-grid: North (NW to NE), East (NE to SE), South (SE to SW) and West (SW to NW). All units that featured 0 and one contour lines, i.e. a local relief of 0 to 3,5° slope, were regarded and recorded as level terrain. The total land area and total indigenous forest area was again determined by superimposition on the two forest distribution maps, the results of this investigation being shown in Table 27.

The general trend of a strong south-facing inclination of 36,1% of the total land area was expected in view of the delimitation of the study area along the Outeniqua range watershed line. Much of the "level" terrain also has a southern inclination. This meant that the north-facing slopes of the Outeniqua range were automatically excluded from the survey. Apart therefrom, the fairly equal distribution in surface area of north-, east-, and west-facing slopes, respectively 12,1%, 10,8% and 10,7%, is nevertheless significant and lends itself well to comparisons. The relatively low forest cover on northern and western aspects must be closely associated with a higher insolation factor, although northern aspects in particular, receive a lower rainfall than other aspects. The relatively low percentage forest cover of 11,94% on level terrain (Table 27) is probably an important indicator that orographic rainfall determines much of the forest location pattern.

TABLE 27 THE EFFECT OF ASPECT ON FOREST COVER

ASPECT TYPES	TOTAL LAND AREA		FOREST AREA		PERCENTAGE FOREST COVER
	Ha	%	Ha	%	
North	54 175	12,1	5 154	7,8	9,51
South	161 708	36,1	30 392	46,3	18,79
East	48 259	10,8	7 296	11,1	15,12
West	47 976	10,7	6 704	10,2	13,97
Level	135 461	30,3	16 167	24,6	11,94
TOTALS	447 579	100,0	65 713	100,0	14,68 average

Representation of aspect for purposes of statistical analysis presented initial problems: How could aspect be expressed in figure values intelligibly? Aspect is associated with inclination towards the sun, and the determination of an "insolation index" appeared a logical solution. The average slope for the Southern Cape is just above 8°, calculated from the macro-terrain by the conventional "sum-of-squares" method, i.e.

MACRO-TERRAIN*

Average Slope		% Land Area		S.S.
$(2,5)^2$	x	41,9	=	261,9
$(8,0)^2$	x	36,4	=	2 329,6
$(13,5)^2$	x	14,7	=	2 679,1
$(18,5)^2$	x	5,8	=	1 985,1
$(23,0)^2$	x	1,2	=	634,8
TOTALS		100,0		7 890,5

$$\text{Average slope} = \sqrt{\frac{7\,890,5}{100}} = 8,88°$$

* Data from Tables 18 and 19

The average inclination of the sun for the various aspects on 8° slopes was hereafter calculated at equinoxes, viz:

Aspect	Sun Inclination
North	$(90 - 34 + 8)° = 64°$
South	$(90 - 34 - 8)° = 48°$
East and West	$(90 - 34 - \frac{8}{2})° = 52°$

For level terrain the 8° average slope was of course disregarded, the average inclination of the sun being (90 - 34°) = 56° at equinoxes. The natural sine for each angle provided the direct aspect index used to test significance (Table 28 and Fig.30). The treatment concerned proved highly significant.

TABLE 28 ASPECT - SIMPLE REGRESSION ANALYSIS OF THE DIRECT INSOLATION INDEX

X-VARIABLE		Y-VARIABLE	
Aspect Type	Sin Angle	Percentage	Angular Transformation
1. North	0,8988	9,51	17,96
2. Level	0,8290	11,94	20,22
3. West	0,7880	13,97	21,95
4. East	0,7880	15,12	22,89
5. South	0,7431	18,79	25,69
r-value = -0,9718 t-value = -7,1385 (> 99%)			

Frank and Lee (1966) devised tables of a radiation index for mid-latitudes (30 - 50°), which feature the following indexes for a 10% slope, i.e. approximately 6°, at 34° latitude:

Northern aspect	=	705,4
Level terrain	=	760,3
East and West aspect	=	759,3
South aspect	=	807,6

In a separate treatment the Frank and Lee Insolation Index was subjected to the same simple regression analysis as that in Table 28, with the following results:

r-value	=	- 0,9470
t-value	=	- 5,1068 (> 99%)

Fig. 30 and Fig. 31 show the two regression lines concerned. The aspect index can and in fact should have been improved upon, by distinguishing between eastern and western aspects. Western aspects are much warmer than eastern slopes. This would require the use of a temperature parameter. However, since the simple regression tests were intended to only broadly verify the choice of factors affecting the forest distribution pattern, this matter was not pursued any further.

5.3.5 Altitude

The importance of altitude or elevation, as a temperature parameter influencing forest distribution, has been recognised by Stern and Roche (1974, p. 208), who regard it as one of the three more important abiotic criteria of variation in forest distribution patterns world-wide. Banerjee (1977, p. 177) used elevation as main variation basis to study the effects of a variety of human and natural factors on forest species distribution in India. The method of expressing elevation is either a direct one of absolute height, or one associated more directly with temperature. An altitude index can possibly be calculated based on the mean adiabatic temperature lapse rate of 0,6°C per 100 m rise in altitude (Richards, 1952, p. 358; Spurr, 1964, p. 41), but again the more direct expression of altitude in terms of metres above sea-level was thought

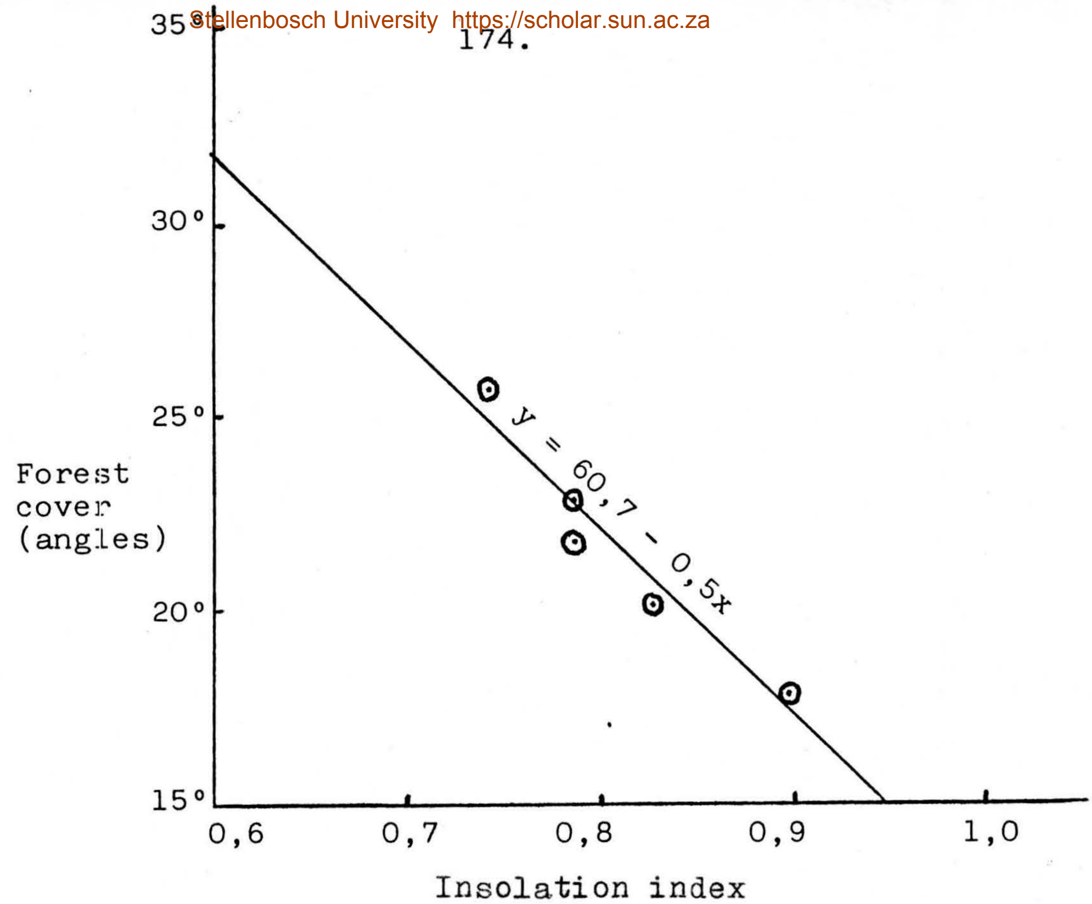


Fig. 30 Aspect according to a direct insolation index: linear regression analysis.

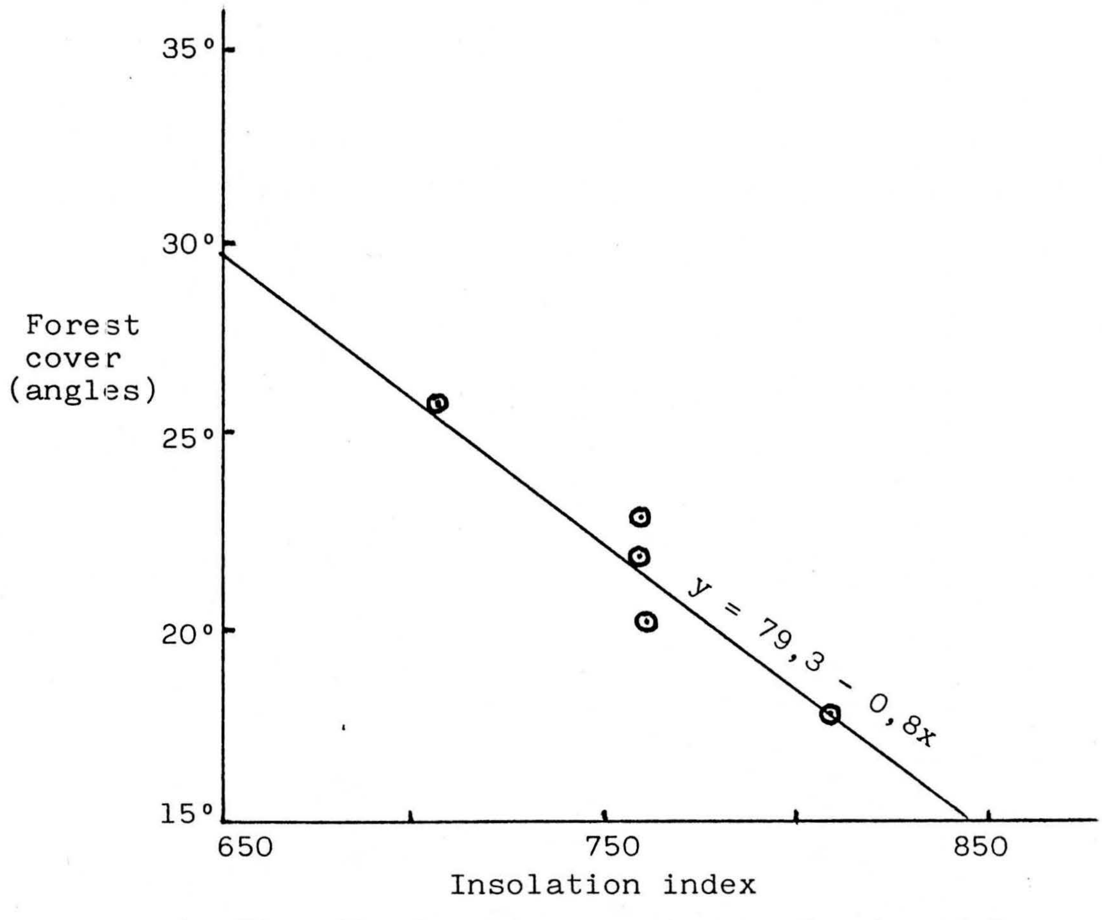


Fig. 31 Aspect according to Frank and Lee insolation index: linear regression analysis.

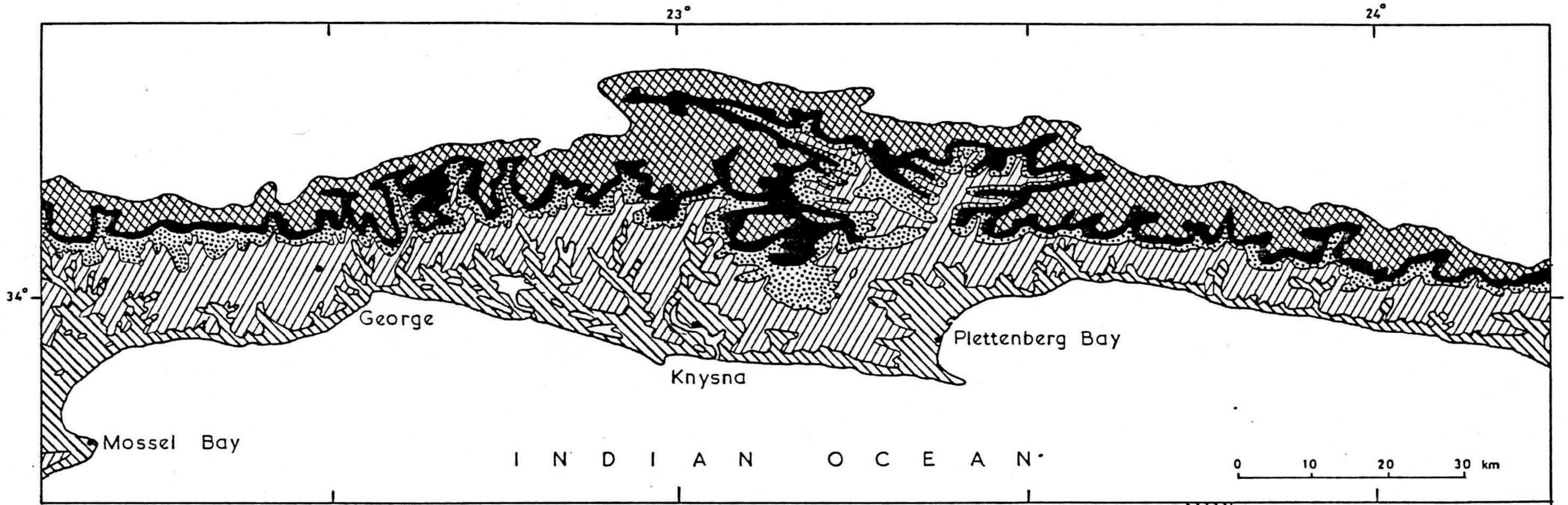
more appropriate for variance analysis to follow. Haggett (1968, p. 320) actually used elevation as a parameter of his terrain index.

Based on topographical data appearing on the 1 : 250 000 top-cadastral maps (3 322 Oudtshoorn and 3 324 Port Elizabeth), which feature 150 m contour intervals, five altitude types were distinguished. Fig. 32 shows these five types. This map was again superimposed on the two forest distribution maps (Fig. 6 and Fig. 7), the results of this investigation featuring in Table 29.

TABLE 29 THE EFFECT OF ALTITUDE ON FOREST LOCATION

ALTITUDE TYPES (m)	TOTAL LAND AREA		TOTAL FOREST AREA		PERCENTAGE FOREST COVER
	Ha	%	Ha	%	
0 - 150	71 551	16,0	12 960	19,7	18,11
151 - 300	152 560	34,1	28 593	43,5	18,74
301 - 450	58 691	13,1	14 380	21,9	24,50
451 - 600	51 172	11,4	5 480	8,3	10,70
> 600	113 605	25,4	4 300	6,6	3,78
TOTALS	447 579	100,0	65 713	100,0	14,68 average

Of the indigenous forests of the Southern Cape 85% are located below 450 metres on 63,2% of the total study area (Table 29). What appears readily forthcoming from Table 29 is that forests appear to reach climax distribution in the mid-elevations gradually receding into both extremes (Fig. 32). This is borne out in Table 29 by the fact that 43,5% of the forests are located between 150 metres and 300 metres altitude and the high percentage forest cover of 24,5% between 300 metres and 450 metres. The above assertion is further borne out by regression analysis (Fig. 33 and Table 30).



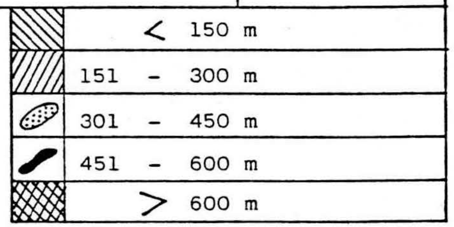


Fig. 32 Elevation type of the Southern Cape.

TABLE 30 ALTITUDE : LINEAR REGRESSION ANALYSIS

X-VARIABLE	Y-VARIABLE	
Average Elevation (m)	Percentage	Angular Transformation
76	18,1	25,18
229	18,7	25,62
381	24,5	29,67
533	10,7	19,09
686	3,8	11,24
r-value = - 0,7578 t-value = - 2,0116 ($<$ 95%)		

Though statistically insignificant with linear regression correlation ($y = a + bx$), curvilinear regression ($y = a + bx + cx^2$) proved more successful (Fig. 33), the results being:

r-value = 0,9549

F-value = 10,3385 ($>$ 95%)

The result of the curvilinear regression analysis, though encouraging, are generally not suited for factor analysis.

5.3.6 Accessibility

Describing the Fortaleza Basin of Brazil, Haggett (1968, pp. 314 - 316) mentions the "immediate and drastic" effect of forest clearance during the 19th century, mainly for purposes of establishing coffee plantations. This applied mainly to accessible larger estates. The accessible smaller to medium-sized farms tended to have retained slightly heavier forest cover. For purposes of representing his accessibility factor Haggett subdivided his study area into accessible areas, i.e. those within two kilometers of all compacted dirt roads, and inaccessible areas, i.e. all areas beyond two kilometers.

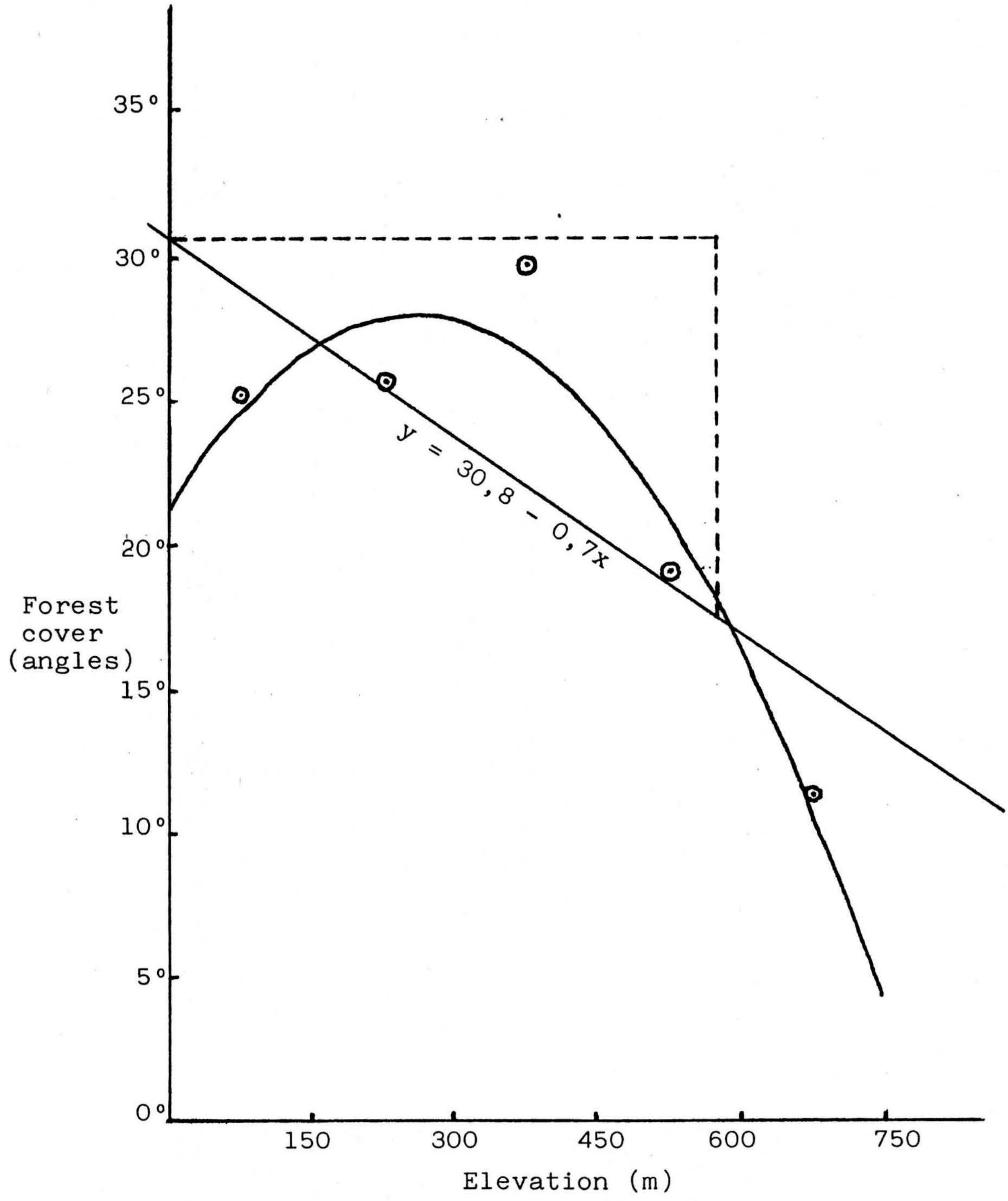


Fig. 33 Linear and curvilinear regression analysis of elevation types.

Although the Southern Cape has probably not experienced quite such a "drastic" period of forest clearance, the accessible forest areas are expected to have been cleared of forest for such purposes as grazing, cultivation of crops, housing as well as for direct timber exploitation. The steeper and more rugged inaccessible places are therefore expected to have retained whatever forest naturally occurred there.

After investigating all the older known access routes and through-ways affecting the earlier Southern Cape transportation system, the following system was devised to represent accessibility:

Accessible areas:
A distance of two kilometers on either side of all major older roads, including the older mountain passes, and a radius of seven kilometers from the four main settlement centres Mossel Bay, George, Knysna and Plettenberg Bay. The term older roads refers to earth-metalled roads, i.e. the pre-tar-road era. The distance of seven kilometer radius from the main centres is based on the argument that this would represent the daily limit of access of an ox-wagon team in the early settlement days, when most forest exploitation took place.

Inaccessible areas:
All land beyond the above limits. Based on the above an accessibility map of the Southern Cape was drawn at two levels only. This map (Fig. 34) was thereupon again compared and superimposed on the forest distribution maps, with the results of this investigation featuring in Table 31.

TABLE 31 THE EFFECT OF ACCESSIBILITY ON FOREST COVER

ACCESS TYPE	TOTAL LAND AREA		TOTAL FOREST AREA		PERCENTAGE FOREST COVER
	Ha	%	Ha	%	
Inaccessible	223 397	49,9	32 926	50,1	14,74
Accessible	224 182	50,1	32 787	49,9	14,63
TOTALS	447 579	100,0	65 713	100,0	14,68 average

The results appear to indicate that accessibility has little to virtually no impact on the forest distribution pattern on a regional basis. However, much of the inaccessible terrain is located in the mountains, which are sparsely forested because of the steep terrain. It is suggested that the accessible areas were more heavily forested before man's impact 200 years ago. Unfortunately the important criterion of fire access was excluded from this accessibility treatment.

5.3.7 Rural Settlement

The approach to this last factor provided initial difficulties. The intention was to test the effect of human population on the forest location pattern, but the problem was which population parameter to use.

In the Southern Cape present-day population figures would tend to stress factors other than specifically forest orientated ones, and it was realised that rural population would have to be stressed more than urban population: Haggett (1968, pp. 320 - 321) represented human effect by a settlement spacing-index, calculated from the mean distance between country towns, and by a rural population density index, calculated by dividing agricultural area by the population of such area. It

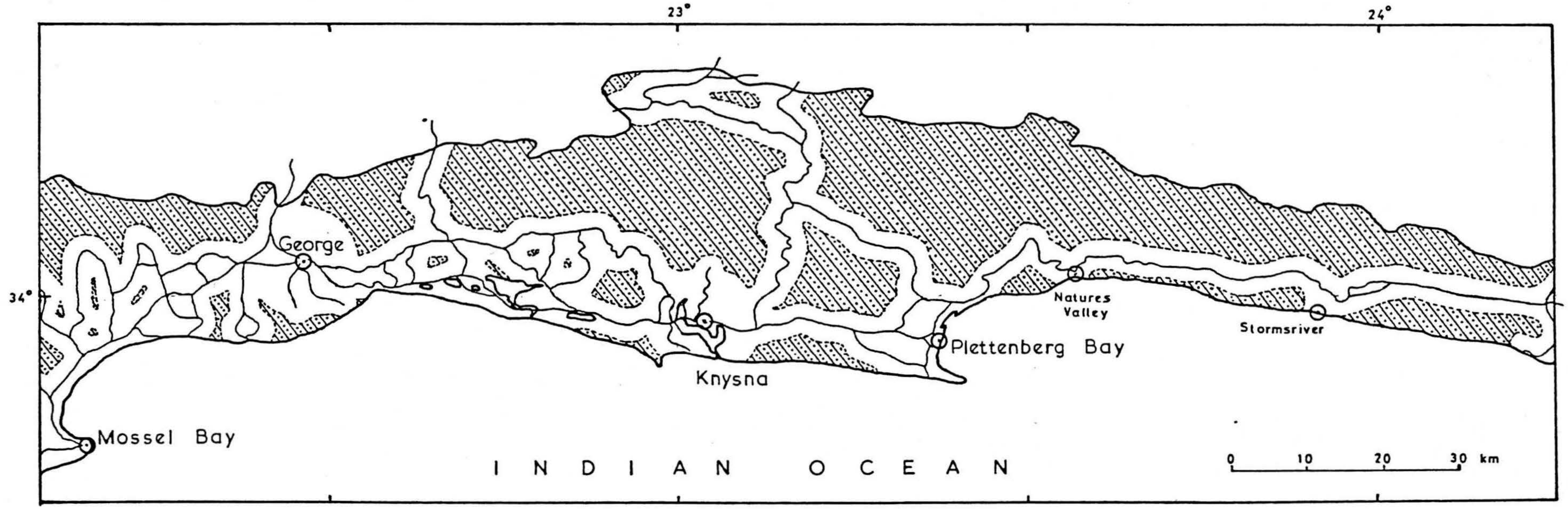


Fig. 34 Human accessibility of the Southern Cape (inaccessible areas shaded).

was finally decided to compile a map, drawn to a scale of 1 : 250 000, but based on information appearing on the S.A. 1 : 50 000 Topographical series (1963), which is based on aerial photographs taken in 1957, and to show on it the total number of buildings found per unit square of one minute by one minute (282 ha). This topographical mapping series does not only show houses or dwellings, but also such buildings as shops and post offices, and thereafter serves to also indicate rural population activity. The resultant rural settlement map (Fig. 35) was thereupon superimposed on the forest distribution maps (Figs. 6 and 7) and the total land area and total forest area under each settlement type determined. From this information the percentage forest cover was calculated (Table 32).

TABLE 32 THE EFFECT OF RURAL SETTLEMENT ON FOREST COVER

SETTLEMENT TYPE (NO. OF BUILDINGS)	TOTAL LAND AREA		TOTAL FOREST AREA		PERCENTAGE FOREST COVER
	Ha	%	Ha	%	
Unpopulated (0)	263 894	59,0	41 143	62,6	15,6
Very sparsely populated (1-5)	66 596	14,9	11 651	17,7	17,5
Sparsely populated (6 - 10)	40 920	9,1	4 928	7,5	12,0
Moderately populated (11-20)	39 211	8,7	5 069	7,7	12,9
Densely populated (21 - 30)	13 258	3,0	1 162	1,8	8,8
Very densely populated (31 +)	23 700	5,3	1 760	2,7	7,4
TOTALS	447 579	100,0	65 713	100,0	14,68 average

Table 32 shows six settlement categories, while Fig. 35 shows only five. The original rural settlement map, drawn to a scale of 1 : 250 000 features all six categories, but in Fig. 35 the settlement types "moderately" (11 - 20 buildings) and "densely" (21 - 30 buildings) populated were grouped together. This was thought necessary to avoid small-scale maps crammed with detail. The statistics in Table 32 show first of all that almost 60% of the Southern Cape is unpopulated, but also that 62,6% of the forest occur on this unpopulated land. When including the very sparsely populated category, i.e. from 0 to 5 buildings per 282 ha unit square, then 80,3% of the forests are located on 73,9% of very sparsely to unpopulated land.

The statistics were subjected to regression analysis. For this purpose percentage forest cover was again converted to angles. Table 33 and Fig. 36 provide details hereof. The treatment clearly indicates a positive correlation between rural settlement and the forest location pattern.

TABLE 33 THE RURAL SETTLEMENT PATTERN: LINEAR REGRESSION ANALYSIS

X-VARIABLE	Y-VARIABLE	
(Average No. of Buildings)	Percentage	Angular Transformation
0	15,6	23,26
2,5	17,5	24,73
8,0	12,0	20,27
15,5	12,9	21,05
25,5	8,8	17,26
35,5	7,4	15,79

r-value = - 0,9426

t-value = - 5,6460 (> 99%)

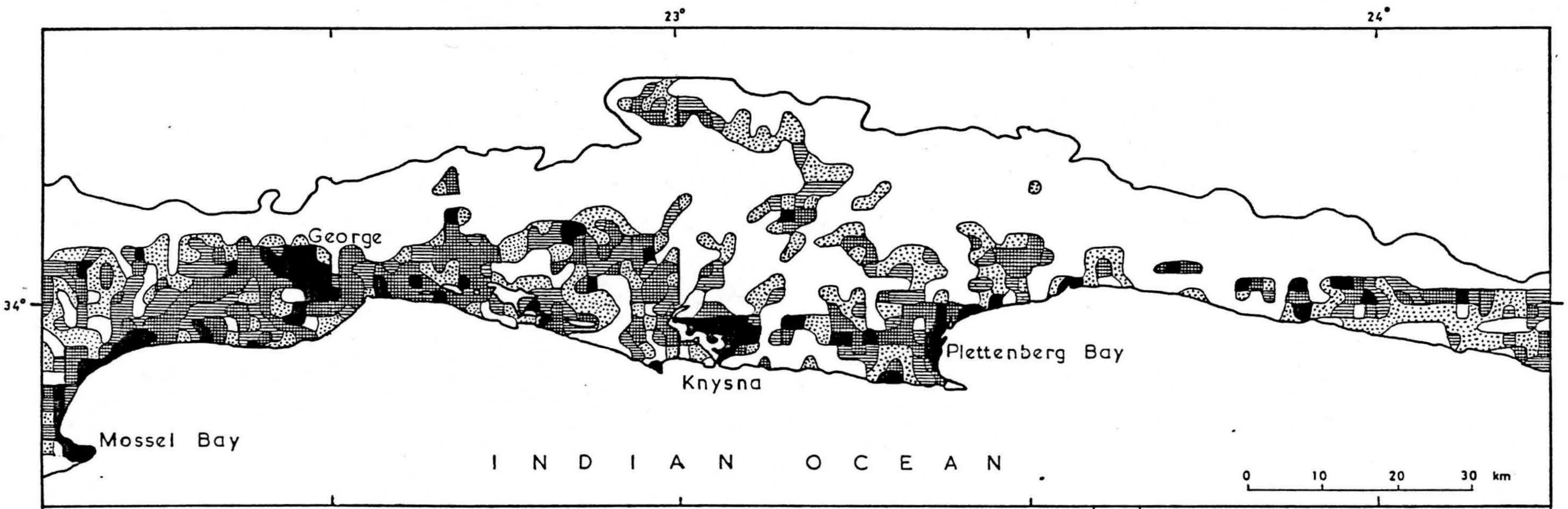


Fig. 35 The rural settlement pattern of the Southern Cape for 1957.
(Based on number of buildings per 282 ha square).

Unpopulated	:	0
Very sparce	:	1 - 5
Sparce	:	6 - 10
Dense	:	11 - 30
Very dense	:	> 30

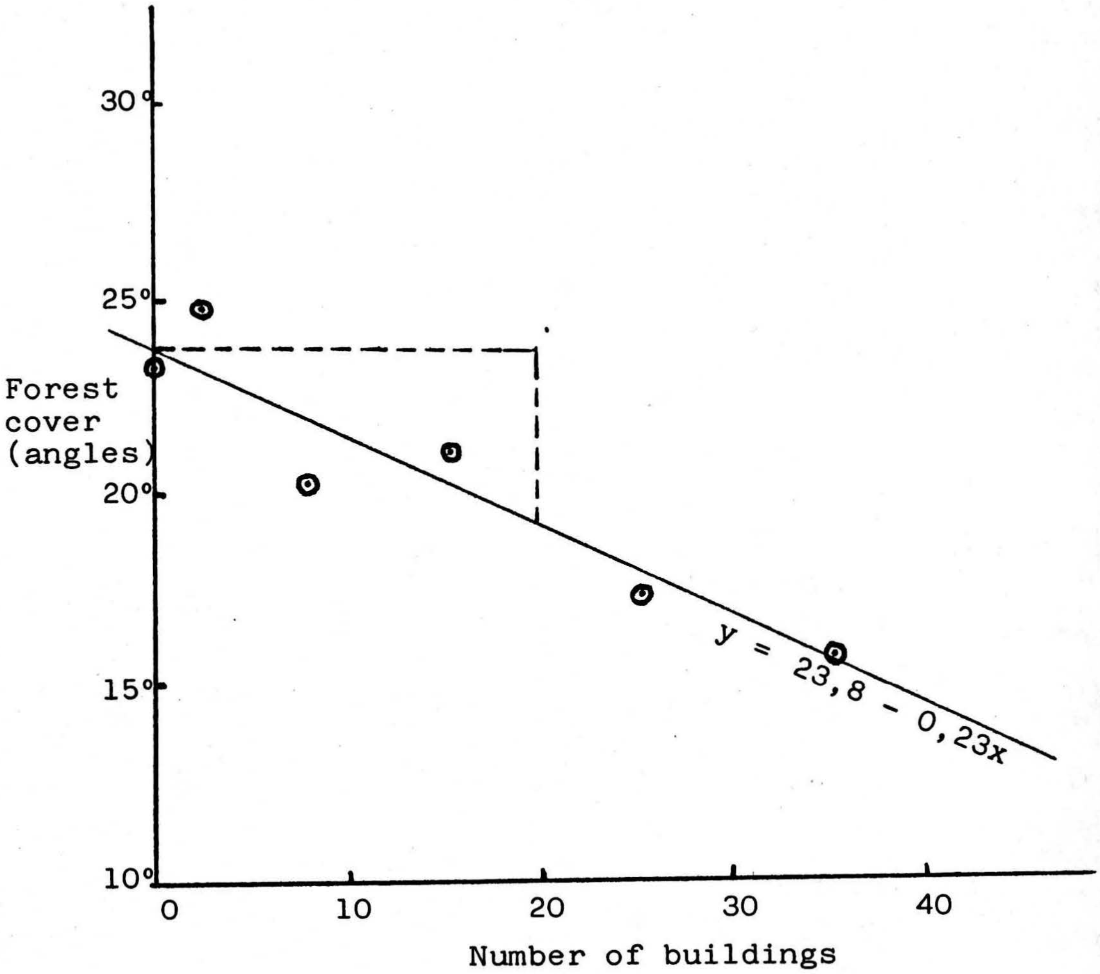


Fig. 36 Rural settlement: linear regression analysis.

5.3.8 Summary

The treatment and discussion of the independent effects of eight selected factors, i.e. univariance analysis, on the location pattern of the indigenous forests of the Southern Cape, is summarised in Table 34.

TABLE 34 SUMMARY OF FACTORIAL ANALYSIS

Factor Type (Variable)	Degrees of Freedom	Correlation Coefficient	Significance (Confidence Level)
Macro-terrain	5	- 0,9687	99%
Micro-terrain	6	- 0,7746	Insignificant
Rainfall	8	0,9750	99,9%
Geological formations	6	0,9903	99%
Aspect (direct)	5	- 0,9718	99%
Aspect (Frank and Lee)	5	- 0,9470	99%
Altitude (linear)	5	- 0,7578	Insignificant
Altitude (curvilinear)	5	- 0,9549	95%
Accessibility	2	-	Not tested
Rural settlement	6	- 0,9426	99%

Table 34 shows that the location pattern of the indigenous forests of the Southern Cape as a region is well explained by the individual impact of precipitation in particular, but also by degree of slope, geological formation, aspect and the rural settlement pattern. It is important though to view the forest location pattern on the impact of the combined forces of variables concerned, i.e. on their multivariance, and in particular on the interaction of such variables on a particular forest location site. This involves viewing the factors of Table 34 on their wider regional impact and on their more localised impact by multivariance analysis.

5.4 FACTORIAL ANALYSIS OF SELECTED REGIONAL FACTORS

5.4.1 Approach

The method selected for analising the effect of the eight factors mentioned in the previous chapter, is that of a factorial design based on variance analysis. This method explores the effects of each factor, but also those of all the possible combinations at different factor levels in order to understand the ways in which each factor is possibly modified by variation in the other.

Each factor was tested, for practical reasons, at two levels only (Davies, 1967, p. 275; Haggett, 1968, p. 316), a positive and a negative forest cover level, after Haggett's (1968) treatment of the Fortaleza Basin. The plotting of boundaries for all eight factors, however, provided extreme difficulties of a maze of factor combinations, virtually impossible to control and accommodate. Eight factor levels would require the Southern Cape study area to be divided into 2^8 = 256 different factorial combinations. It was therefore decided to divide the eight factors into two groups of four factors each, for the following considerations:

(a) The accommodation problem of eight factors, which involve 256 factorial combinations, was no practical proposition. Two separate designs of four factors each, would involve 32 combinations only, i.e. 16 within each design, which is far easier to manage both in the mapping designs and in statistical analysis;

(b) all eight factors were fully described, meaning that the model was deterministic, without any estimation. Such a model lends itself better to 'manipulations' of this kind than sampling designs with a random component or stochastic models;

(c) all factors were tested at more than two levels and subjected to statistical significance tests beforehand, so that the populations were controlled;

(d) the factors themselves were expressed in their simplest form and the selection of four factors into two groups was thereby easier to 'balance', than would otherwise have been the case.

Another problem was how to arrange the two factorial groups, i.e. which variables to group together, not that this problem should be overrated, because it was the intention to combine the results of the separate factorial analysis at the end for a combined effect. However, the four-factor grouping would have to be as balanced as possible, without grouping similar criteria together unnecessarily.

The eight factors represent the following environmental criteria:

Climate, which is represented by rainfall, altitude and aspect;

Physiography, represented by macro-terrain (average slope), micro-terrain (ruggedness) and to a certain extent aspect;

Human impact, represented by accessibility and the rural settlement pattern;

Geological formations.

It was decided to divide the eight factors into the following two groups:

Group A

Macro-terrain types, rainfall, geology and accessibility;

Group B

Micro-terrain types, aspect, altitude and rural settlement.

The group A design was chosen to represent broader regional trends, while group B factors were expected to reveal more localised detail. In order to test the validity of such grouping, the group A factors were subjected to a full regional analysis, involving the whole study area.

5.4.2 Plotting the Variables of Group A Factors

Based on the data collected on each of the four factors concerned, each factor had to be expressed clearly and logically acceptable at two treatment levels. Since the objective of the study is the explanation of the forest location pattern, the obvious dividing criterion would be between a positive and a negative factor level based on forest distribution, i.e. the mean forest cover of 14,68%. This means that the positive value would be all treatment levels exceeding 14,68%, while those below this figure represented the negative forest location value. Based upon this distinction, the four factors were represented as follows:

F A C T O R	POSITIVE VALUE	NEGATIVE VALUE
A. Macro-terrain	Slopes $< 11°$	Slopes $> 11°$
B. Rainfall	Annual rainfall $>$ 700 mm	Annual rainfall $<$ 700 mm
C. Geological formations	Schists, shales and sandstones	Conglomerates, recent deposits and granites
D. Accessibility	Inaccessible areas	Accessible areas

The reasons for these subdivisions should be clear when referring to the relevant results obtained in the multi-level treatment carried out. There the plains and gentle foothills of the macro-terrain type featured 18,53 and 14,84% forest cover respectively, while the foothills, mountains and steep mountains featured figures of 7,22, 6,86 and 4,57% respectively. The factor rainfall provided a problem in this regard, since the 701 to 800 mm rainfall criterion features a below-average 13,3% forest cover, however represents 21,5% of the Southern Cape forests. It was decided to include the marginal 701 to 800 mm level on the positive side because of this tendency. The Cape Granites, superficial sand deposits and Enon conglomerates feature forest percentage cover of 3,28, 4,71 and 8,14% respectively, while TMS, the Bokkeveld shales and Malmesbury shales and schists feature above-average percentages of 16,00, 21,31 and 21,56 respectively. The statistics on accessibility do not reveal a clearcut tendency eitherway, nevertheless it was assumed that inaccessible areas have been more forest persistant than the accessible areas.

Boundaries for each of the four levels were plotted from the respective existing maps onto a standard

1 : 250 000 map, covering the whole study area (Fig. 37). Each sector was classified in terms of the 16 possible factor-combination types as indicated in the last vertical column of Table 35:

Factors A, B, C and D are expressed at two levels: a, b, c and d as the positive and I as the negative levels.

TABLE 35 THE SOUTHERN CAPE : BASIS FOR FACTOR-COMBINATION

FACTOR A MACRO-TERRAIN	FACTOR B RAINFALL	FACTOR C GEOLOGY	FACTOR D ACCESSIBILITY
a Lower slopes	ab High	abc Shales	abcd Inaccessible
			abc Accessible
		ab Others	abd Inaccessible
			ab Accessible
	a Low	ac Shales	acd Inaccessible
			ac Accessible
		a Others	ad Inaccessible
			a Accessible
I Steep	b High	bc Shales	bcd Inaccessible
			bc Accessible
		b Others	bd Inaccessible
			b Accessible
	I Low	c Shales	cd Inaccessible
			c Accessible
		I Others	d Inaccessible
			I Accessible

5.4.3 Forest Cover

Forest cover was determined for each of the 16 factor-combinations in the same way as the individual factors were treated, namely by superimposing Fig. 37

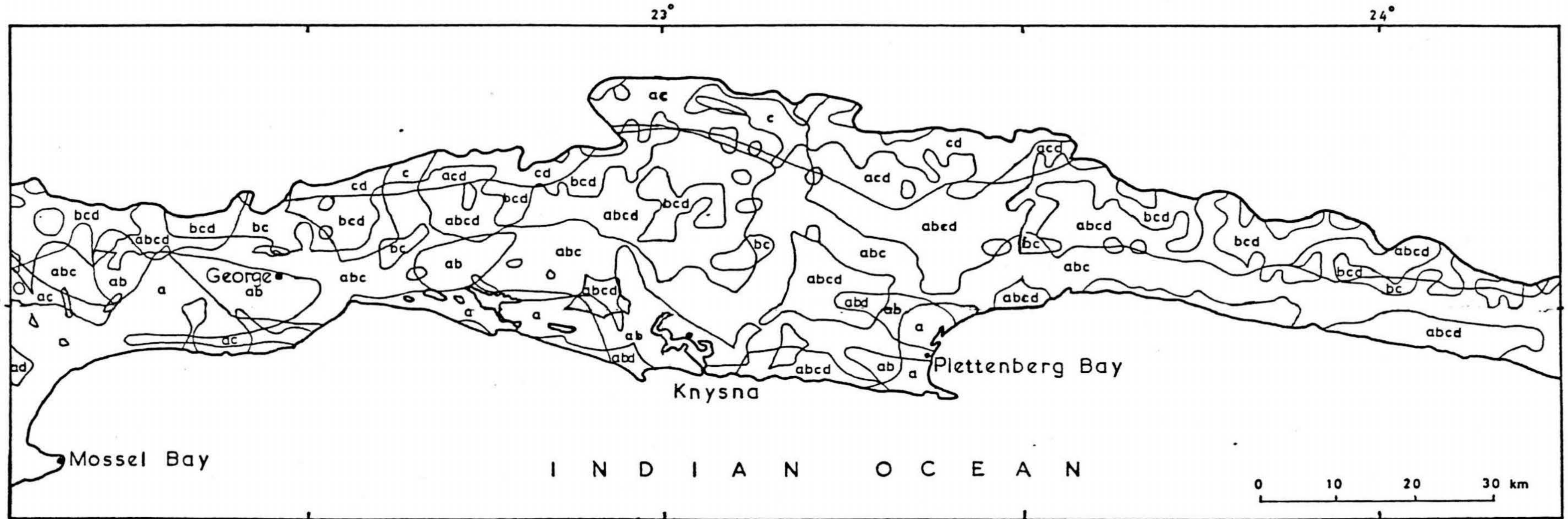


Fig. 37 Factorial combinations within Southern Cape as region.

a	Macro-terrain	(< 11°)
b	Rainfall	(> 700 mm)
c	Geology	(schists, sandstones (and shales)
d	Accessibility (inaccessible areas)	

on the Forest Distribution Map and Forest Distribution Control Map (Fig. 6 and 7) and determining the total land area and the total forest area for each factor. Table 36 provides the results of this treatment.

TABLE 36 FOUR-FACTOR COMBINATION: REGIONAL ANALYSIS. DETERMINATION OF FOREST COVER

Factor Combination	TOTAL AREA		FOREST AREA		% Forest Cover	Angular Transformation
	Ha	%	Ha	%		
abcd	115 934	25,9	26 925	41,0	23,22	28,79
abc	106 761	23,8	27 292	41,5	25,56	30,40
abd	5 339	1,2	1 297	2,0	24,29	29,53
ab	34 981	7,8	2 113	3,2	6,04	14,18
acd	19 517	4,3	338	0,5	1,73	7,49
ac	22 470	5,0	395	0,6	1,76	7,71
ad	4 316	1,0	28	0,1	0,65	4,80
a	38 436	8,6	508	0,7	1,32	6,55
bcd	54 373	12,1	4 225	6,4	7,77	16,22
bc	14 347	3,2	2 423	3,7	16,89	24,27
bd	113	0,1	-	-	-	-
b	-	-	-	-	-	-
cd	23 664	5,3	113	0,2	0,48	4,05
c	7 187	1,6	56	0,1	0,78	5,13
d	141	0,1	-	-	-	-
I	-	-	-	-	-	-
TOTALS	447 579	100,0	65 713	100,0	14,68 average	

The above results indicate that 82,5% of the forests are explained by the interactions abcd and abc, which cover 49,7% of the total area.

5.4.4 Multi-variance Analysis

Analysis of variance of the above results was carried out using the Standard Yates 2^n factorial design (Davies, 1967, pp. 274 - 280). The method and results of this analysis appears in some detail, because it was extensively used in subsequent analyses as well, where only final results are tabulated (Table 37).

TABLE 37 ANALYSIS OF VARIANCE: REGIONAL ANALYSIS BY YATES 2^n FACTORIAL DESIGN

Treatment Combination	Response (Angles)	TREATMENT (1)	(2)	(3)	(4)	EFFECT $\frac{(\text{Col. }4)}{8}$	SUM OF SQUARES $\frac{(\text{Col. }4)^2}{16}$
I	0	6,6	20,8	88,3	179,2	-	-
a	6,6	14,2	67,5	90,9	79,8	9,975	398,003
b	0	12,8	34,3	29,5	107,6	13,450	723,610
ab	14,2	54,7	56,6	50,3	45,0	5,625	126,563
c	5,1	4,8	20,8	49,5	69,0	8,625	297,563
ac	7,7	29,5	8,7	58,1	-30,4	-3,800	57,760
bc	24,3	11,6	34,3	11,1	43,0	5,375	115,563
abc	30,4	45,0	16,0	33,9	-19,6	-2,450	24,010
d	0	6,6	7,6	46,7	2,6	0,325	0,423
ad	4,8	14,2	41,9	22,3	20,8	2,600	27,040
bd	0	2,6	24,7	-12,1	8,6	1,075	4,623
abd	29,5	6,1	33,4	-18,3	22,8	2,850	32,490
cd	4,1	4,8	7,6	34,3	-24,4	-3,050	37,210
acd	7,5	29,5	3,5	8,7	- 6,2	-0,775	2,403
bcd	16,2	3,4	24,7	-4,1	-25,6	-3,200	40,960
abcd	28,8	12,6	9,2	-15,5	-11,4	-1,425	8,123
TOTAL	179,2						1 896,344

<u>Check</u>: (1) Total of response = Top figure of column 4

= <u>179,2</u>

(2) Corrected sum of squares = $(0^2 + 6,6^2 + \ldots\text{to}\ldots + 28,8^2) - 179,2^2 \div 16)$

= 3 903,38 - 2 007,04

= 1 896,34

(This figure agrees with the total Sum of Squares column = 1 896,344). The treatment is therefore valid.

For purposes of interpretation an estimate of error variance was required, and in the absence of an external estimate and a reliable internal estimate, the higher order interactions were taken as error (after Davies, 1967, p. 277). The results of analysis of multiple-variance is shown in Table 38.

5.4.5 Summary

Macro-terrain, rainfall and geological formations all appear to have an important impact on forest cover on a regional basis, all showing significance at the 95% confidence level. The interactions feature no significant correlations, although there appears a slight correlation between macro-terrain and rainfall and also between rainfall and geological formations.

What appears evident from this regional treatise is the considerable variability in virtually all four factors within the region. It was therefore feared that the variance trend might be shaded to a greater or lesser degree in specific areas. The following need only serve as examples:

(a) In the western part of the study region the more level areas are bare of forest, while the steeper mountains support forest cover; however in the eastern part the reverse appears true.

(b) Accessibility reveals similar trends, the western areas feature more forest in the inaccessible areas, while the east reveals a reversal of this trend.

It was therefore decided to concentrate more on local study areas. These local areas would have to be fairly homogeneous and yet large enough to warrant full analysis.

TABLE 38 RESULTS OF MULTIPLE-VARIANCE ANALYSIS OF FACTOR EFFECTS ON FOREST COVER

NATURE OF THE EFFECT	SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	CONVENTIONAL SIGNIFICANCE LEVEL
Main factors:	Terrain (a)	1	398,003	99%
	Rainfall (b)	1	723,610	99%
	Geology (c)	1	297,563	95%
	Access (d)	1	0,423	Insignificant
Interactions:	ab	1	126,563	90%
	ac	1	57,760	Insignificant
	ad	1	27,040	Insignificant
	bc	1	115,563	90%
	bd	1	4,623	Insignificant
	cd	1	37,210	Insignificant
Higher order interactions:	abc, abd acd, bcd, abcd	5	21,597 =	Error

NOTE:

The F-value for 1 and 5 degrees of feedom at the

99% confidential level = 16,30 x 21,597 (Error) = 352,031

at the

95% confidence level = 6,61 x 21,597 (Error) = 142,756

at the

90% confidence level = 4,06 x 21,597 (Error) = 87,684

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CHAPTER 6

AN ANALYSIS OF THE LOCATION PATTERN OF THE INDIGENOUS FORESTS OF THE SOUTHERN CAPE : LOCAL STUDIES

6.1 Delimitation of Local Study Areas

For purposes of analysing the impact of a number of selected factors on the Southern Cape forest location pattern on a more local basis, the same procedure was envisaged as that used for the regional factorial analysis. The data, already collected and controlled in vertical one-minute columns for eight independent variables, would be used again, however fragmentary and for specific local study areas only. This also means that the local study areas would be individually treated according to the deterministic approach (Orlóci, 1975, p. 4) and that the local study areas combined would comprise the total Southern Cape study area.

Von Breitenbach (1968, p. 84) divided the Southern Cape into three geographical areas, namely the Outeniqua-Homtini area west of the Knysna river, the Knysna area between the Knysna river and the Keurboomsriver, and the Tsitsikamma area east of the Keurboomsriver.

He further subdivided the three areas into geo-topographical zones, to which he attributes "marked climatical differences".

For purposes of delimitating the local study areas, forest distribution was expressed in graphic form in two ways, namely the forest occurring within vertical columns of five minutes longitude expressed as a percentage of the total forest area (Fig. 38); and the forest within five minute vertical longitude

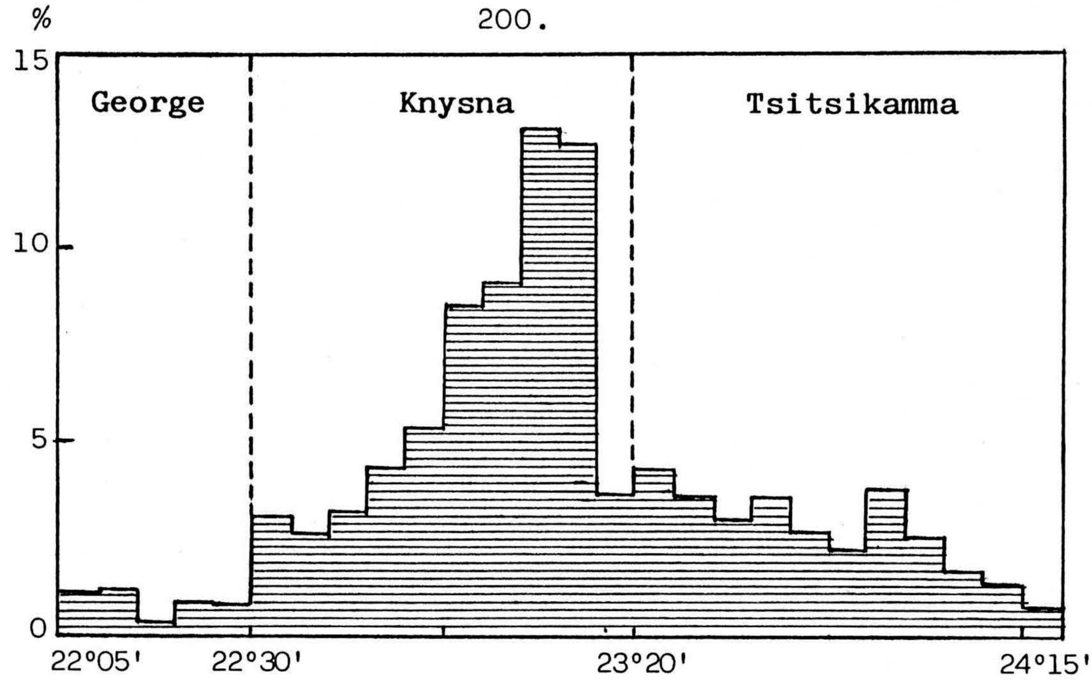


Fig. 38 The indigenous forest of the Southern Cape expressed as a percentage of the total forest area.

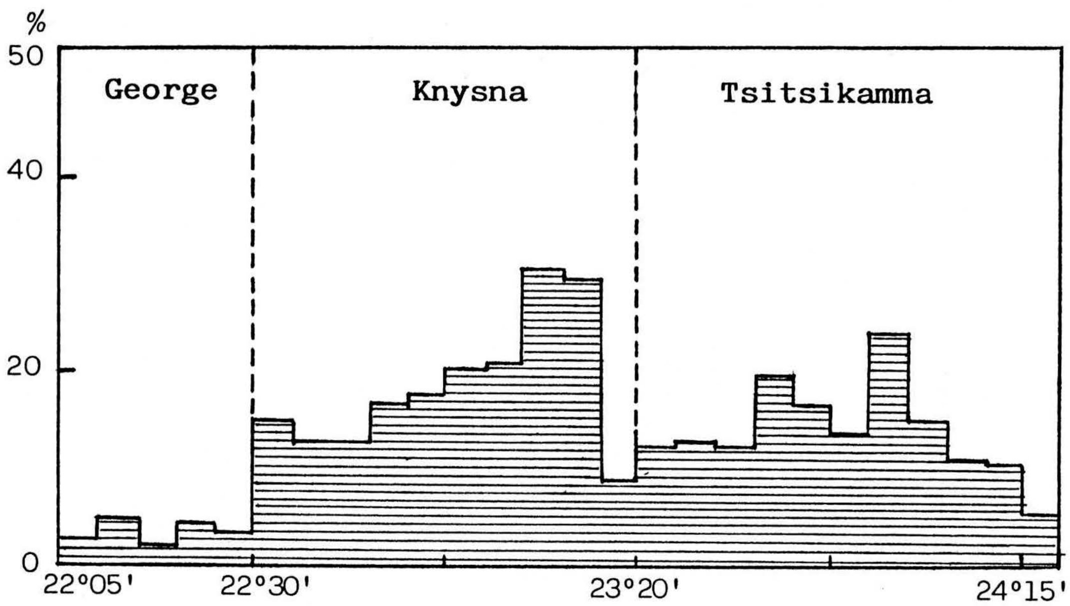


Fig. 39 The indigenous forest of the Southern Cape expressed as a percentage of the total land area.

columns expressed as percentage of the total land area (Fig. 39). Three locational trends could be discerned, namely the central Knysna-orientated forest heartland area, the eastern Tsitsikamma plateau-orientated forest area and the western George mountain-orientated forest area. The actual delimitation boundaries west- and eastwards were carefully explored and finally selected as follows:

(a) George Mountain Forest Area ranging from 22°05' E (Mossel Bay) in the west to 22°30' E (George), and again from the sea-shore to the Outeniqua watershed;

(b) Knysna Forest Area ranging from 22°30' (George) to 23°20' E (Plettenberg Bay);

(c) Tsitsikamma Forest Area: from 23°20' (Plettenberg Bay to 24°15' E (Kareedouw).

This delimitation into three local areas therefore involves the whole Southern Cape study area. Table 39 features details of the respective total surface and forest areas involved. The data concerned was derived at directly from the regional treatment.

The George Mountain forests occur along the slopes of the Outeniqua mountains as well as along the more protected coastal embankment, more or less like a pair of horns pointing west from the Knysna forest 'heartland'. This local study area covers 18,5% of the Southern Cape area as a whole, but only 4,5% of the Southern Cape forests and features an average forest cover of only 3,6%.

The Knysna forest area is distributed over about half of the total study region, but contains as much as 65,8% of all the forests of the Southern Cape.

The forest cover of close to 20% justifies the term 'forest heartland'.

The Tsitsikamma local forest area is located on 31,8% of the Southern Cape and contains 29,7% of all the forests concerned. The forest cover of 13,8% is close to the regional average of 14,7%.

TABLE 39 DELIMITATION OF THE LOCAL STUDY AREAS OF THE SOUTHERN CAPE

LOCAL STUDY AREA	TOTAL LAND AREA		FOREST AREA		PERCENTAGE FOREST COVER
	Ha	%	Ha	%	
George Mountain Forest Area	82 964	18,5	2 960	4,5	3,6
Knysna Forest Area	222 287	49,7	43 225	65,8	19,6
Tsitsikamma Forest Area	142 328	31,8	19 528	29,7	13,8
TOTALS	447 579	100,0	65 713	100,0	14,7% average

6.2 Representation of Local Factors

The method adopted in the regional study was followed and the percentage forest cover was determined for each of the eight factors.

These percentages were again converted to angles with the aid of Angular Transformation Tables. Angles were used in all statistical treatments. The intention with the local treatments was not to fully explain the effects of each factor concerned, but rather to either confirm the regional trend or to show up anomalies to such regional trends. For this reason the last column of the relevant tables provides the regional effect.

6.2.1 Macro-terrain Type

The direct relationship between macro-terrain (or average slope) and the forest cover in the George mountain forest area is striking, when compared with the inverse relationship existing in the region as a whole and both the Knysna and Tsitsikamma local study areas (Table 40).

TABLE 40 THE EFFECT OF MACRO-TERRAIN ON FOREST COVER IN LOCAL AREAS

FACTOR	FOREST COVER						
MACRO-TERRAIN TYPES	GEORGE MOUNTAIN FORESTS		KNYSNA FORESTS		TSITSIKAMMA FORESTS		SOUTHERN CAPE
	%	Angles	%	Angles	%	Angles	%
Level	2,0	8,13	25,1	30,07	21,2	27,42	18,5
Gently sloping	3,9	11,39	19,0	25,84	13,7	21,72	14,8
Moderate foothills	7,1	15,45	10,0	18,43	4,4	12,11	7,2
Mountains	9,1	17,56	7,2	15,56	5,2	13,18	6,9
Very steep slopes	8,6	17,05	3,9	11,39	3,6	10,94	4,6
Mean forest cover	3,6%		19,6%		13,8%		14,7%
r-value	0,9529		- 0,9934		- 0,9278		- 0,9687
t-value	5,4419		-14,9754		- 4,3073		- 6,7602
Confidence level	95%		99%		95%		99%

This means that the George mountain forest cover increases with increase in slope, whereas the reverse tendency is apparent in the other local forest areas. It is important to note that all three treatments are significant to the 95% confidence level, and that of Knysna as much as 99%.

A further factor of significance is the fact that "gently sloping" terrain (6° - 11° slope) represents the dividing line between above and below-average forest cover in all three local areas (Table 40); i.e. 3,9% forest cover in the George area which has a mean forest cover of 3,6%; 19,0% in the Knysna area with a mean forest cover of 19,6%; 13,7% in the Tsitsikamma area which features a mean of 13,8%, and 14,8% for the Southern Cape, which features an average of 14,7% for the areas as a whole. Another very revealing trend is the relatively high forest cover of the steeper terrain in the western sectors (around 9% forest cover), receding to less than half of this in the wetter east.

6.2.2 Rainfall

The regional trend of an increase in forest cover with increase in rainfall is common to all three local study areas. This direct relationship appears so regular that anomalies such as the 1,5% cover in the 701 - 800 mm region in the George mountain area (Table 40) may in fact be directly due to man's exploitation of forests for agricultural land gain, alternatively the effects of fires. The highest percentage forest cover is found in the highest rainfall region within each local area, particularly prominent in the Knysna forest heartland. A feature common to all three sub-localities is the low forest cover below 600 mm rainfall. The relatively high r-values in all three treatments confirm the strong direct relationship which exists between precipitation and forest cover.

TABLE 41 THE EFFECT OF RAINFALL ON FOREST COVER OF LOCAL AREAS

FACTOR	FOREST COVER						
RAINFALL (mm)	GEORGE MOUNTAIN FORESTS		KNYSNA FORESTS		TSITSIKAMMA FORESTS		SOUTHERN CAPE
	%	Angles	%	Angles	%	Angles	%
< 500	0,0	0,00	0,0	0,00	-	-	0,0
501 - 600	0,0	0,00	0,7	4,80	0,0	0,00	0,4
601 - 700	4,8	12,66	1,0	5,74	1,5	7,03	2,0
701 - 800	1,5	7,03	12,9	21,05	19,8	26,42	13,3
801 - 900	5,7	13,81	21,3	27,49	6,2	14,42	15,4
901 - 1 000	7,0	15,34	38,3	38,23	12,7	20,88	23,2
1 001 - 1 100	6,7	15,00	65,2	53,85	14,8	22,63	29,8
1 100 >	17,4	24,65	67,2	55,06	23,1	28,73	30,5
Mean forest cover	3,6%		19,6%		13,8%		14,7%
r-value	0,9149		0,9818		0,8179		0,9750
t-value	5,5513		12,6575		3,1790		10,7434
Confidence level	99%		99%		95%		99%

6.2.3 Geology

The effect of geological formation on forest cover (Table 42) is not readily forthcoming from the local study areas. This is partly due to some of the formations being untested, e.g. Cape Granites and Malmesbury shales are absent in the Tsitsikamma, so are Bokkeveld shales in the George area. It appears as though the impact of geology is largely sub-ordinate to that of physiography and climate, an example being Bokkeveld shales in the Knysna and Tsitsikamma areas. Bokkeveld covers

TABLE 42 THE EFFECT OF GEOLOGICAL FORMATIONS ON THE FOREST COVER OF LOCAL AREAS

FACTOR	LAND AND FOREST AREAS (ha) AND FOREST COVER (%)									
GEOLOGICAL FORMATION	GEORGE MOUNTAIN FORESTS			KNYSNA FORESTS			TSITSIKAMMA FORESTS			SOUTHERN CAPE
	Land	Forest	%	Land	Forest	%	Land	Forest	%	%
Cape Granite	27 288	106	0,4	7 066	1 021	14,5	-	-	-	3,3
Table Mountain Sandstone	27 707	1 797	6,5	146 071	32 066	22,0	125 415	14 021	11,2	16,0
Malmesbury Shales	14 724	951	6,5	24 469	7 533	30,8	-	-	-	21,6
Bokkeveld Shales	-	-	-	12 865	35	0,3	11 329	5 120	45,2	21,3
Enon Conglomerates	5 680	-	0,0	11 065	1 338	12,1	4 021	352	8,8	8,1
Superficial Deposits	7 565	106	1,4	20 751	1 232	5,9	1 563	35	2,2	4,7
MEAN FOREST COVER	3,6%			19,6%			13,8%			14,7
r-value	0,6247			0,9881			0,9562			0,9902
t-value	1,6002			12,8408			4,6199			14,1862
Confidence value	Insignificant			99%			95%			99%

fairly equal surface areas of about 12 000 ha in both these localities, yet show a marked difference in forest cover of 0,3% and 45,2% of the respective areas. On the whole, though, the sandstones and shales feature above-average forest cover, while granites, the conglomerates and unconsolidated sands are fairly bare of forest.

The direct relationship between land surface area and indigenous forest area was used in the statistical analysis in Table 42. It was for this reason not necessary to convert percentage forest cover to angles, since percentage data was not used in the correlation and significance tests. The high confidence levels for both Knysna and the Tsitsikamma ($\leqslant$ 0,05%) is noteworthy.

6.2.4 Accessibility

The effect of human access on forest cover in the three local study areas is indeed revealing (Table 43).

TABLE 43 THE EFFECT OF HUMAN ACCESS ON FOREST COVER

FACTOR TYPE	FOREST COVER			
	GEORGE %	KNYSNA %	TSITSIKAMMA %	SOUTHERN CAPE %
Accessible	2,3	17,4	22,7	14,6
Inaccessible	6,6	21,6	8,9	14,7
Mean Forest Cover	3,6	19,6	13,8	14,7

Forests are located in the more inaccessible areas in river valleys and along steeper mountain slopes in the George vicinity, while the opposite applies to the Tsitsikamma, where the accessible more level areas are fairly densely forested (22,7% cover). This inverse relationship can however not be explained by the impact of human access alone, but by the combined effects of such factors as precipitation, aspect and steepness of terrain. It is nevertheless revealing how deceptive a regional study can be, since the percentage forest cover appears altogether undifferentiated for the Southern Cape as a whole (Table 43). The statistics in Table 43 do not lend themselves to regression analysis. The chi-square (x^2) test, based on an average population hypothesis, is also not considered applicable here.

6.2.5 Micro-terrain Type

Level terrain and the steeper terrain types show the greatest variation between the three sub-regions (Table 44). On level terrain the George area features a very low 0,9% forest cover, the Tsitsikamma an above-average 15,1%, while the Knysna forest heartland area features 18,8% forest cover, which however is below its average of 19,6%.

The George area features its highest forest cover of 9,7% in mountains with an average slope of between 17° to 26°. Only the very steep slopes have no forests, mainly due to the inability to develop a soil cover. The correlation is however low ($r = 0,3188$) and the treatment insignificant. The Knysna area features its highest forest cover of 33,4% along the more gentle slopes between 3,5° to 7° and the more "rugged" drainage basins. They drop markedly in both gradient directions therefrom. The mountains are virtually bare of forest. The treatment effect of micro-terrain on forest area is only significant in the Knysna sub-region (99% confidence level). The Tsitsikamma reveals a very similar trend to Knysna, with the highest forest cover of 29,5% in the 3,5 - 7° average slope type, receding to both extremes therefrom. The treatment effect is however insignificant.

The analysis of micro-terrain shows how great the variation can be between regional and local trends.

TABLE 44 THE EFFECT OF MICRO-TERRAIN ON FOREST COVER

FACTOR	FOREST COVER						
MICRO TERRAIN TYPE	GEORGE MOUNTAIN FORESTS		KNYSNA FORESTS		TSITSIKAMMA FORESTS		SOUTHERN CAPE
	%	Angles	%	Angles	%	Angels	%
Level	0,9	5,44	18,8	25,70	15,1	22,87	12,1
Gentle slopes and rugged drainage	6,8	15,12	33,4	35,30	29,5	32,90	27,7
Moderate slopes	6,6	14,89	23,8	29,20	19,4	26,13	20,5
Foothills	3,5	10,78	9,0	17,46	5,3	13,31	7,0
Mountains	9,7	18,15	1,7	7,49	3,0	9,97	3,4
Very steep slopes	0,0	0,00	0,0	0,00	5,2	13,18	3,8
Mean forest cover	3,6%		19,6%		13,8%		14,7%
r-value	- 0,3188		- 0,9315		- 0,7573		- 0,7746
t-value	- 0,6727		- 5,1224		- 2,3191		- 2,4493
Confidence level	< 95%		99%		< 95%		< 95%

6.2.6 Aspect

The effect of aspect on forest cover in the three sub-regions can best be analysed by comparing each one with that evident in the regional trend (Table 45). This effect must however be compared based on the respective mean forest cover trends. In the George area (mean forest cover of 3,6%) the main diversion from the regional norm is in the north and level aspect types, 1,9% and 0,5% forest cover respectively, which is far below the 9,5%

and 11,9% forest cover of the region at a 14,7% mean forest cover. The Tsitsikamma reveals an above-average 16,3% forest cover on level terrain while that of the region is below average. The Knysna pattern is about the same as the regional one. This is also evident from the high correlation and treatment effect evident (Table 45).

TABLE 45 THE EFFECT OF ASPECT ON FOREST COVER

FACTOR	FOREST COVER						
ASPECT TYPES	GEORGE AREA		KNYSNA AREA		TSITSIKAMMA AREA		SOUTHERN CAPE
	%	Angles	%	Angles	%	Angles	%
North	1,9	7,92	11,5	19,82	7,3	15,68	9,5
South	8,1	16,54	23,1	28,73	17,1	24,43	18,8
East	8,6	17,05	21,3	27,49	8,5	16,95	15,1
West	4,4	12,11	21,1	27,35	7,7	16,11	14,0
Level	0,5	4,05	18,0	25,10	16,3	23,81	11,9
Mean forest cover	3,6%		19,6%		13,8%		14,7%
r-value	- 0,7129		- 0,9810		- 0,4496		- 0,9718
t-value	- 1,7808		- 8,7632		- 0,8718		- 7,1385
Confidence level	< 95%		99%		< 95%		99%

It is noteworthy to compare the level terrain of Table 45 with that of Table 44. These should be the same, yet they differ by a small margin of error.

The cause for this deviation must be sought in independent basic data collection for the two variables concerned, but also in the very small size of the grid-units worked on. The 0,5 x 0,5 minute squares on the 1 : 250 000 scale basic data map amount to nine grid units per 1 cm^2.

6.2.7 Altitude

The effect of elevation on forest cover is evident in the Tsitsikamma (Table 46) with a highly significant treatment effect, with the highest forest cover of 23,7% at lower elevations decreasing steadily with increase in altitude.

TABLE 46 THE EFFECT OF ALTITUDE ON FOREST COVER

FACTOR	FOREST COVER						
ELEVATION TYPE (m)	GEORGE AREA		KNYSNA AREA		TSITSIKAMMA AREA		SOUTHERN CAPE
	%	Angles	%	Angles	%	Angles	%
0 - 150	3,2	10,30	23,8	29,20	23,7	29,13	18,2
151 - 300	1,9	7,92	24,8	29,87	23,0	28,66	18,9
301 - 450	6,5	14,77	35,4	36,51	12,9	21,05	24,7
451 - 600	1,5	7,03	13,2	21,30	8,1	16,54	10,8
601 >	7,2	15,56	4,1	11,68	2,4	8,91	3,8
Mean forest cover	3,6%		19,6%		13,8%		14,7%
r-value	0,3909		- 0,7244		- 0,9748		- 0,7578
t-value	0,7356		- 1,8203		- 7,5647		- 2,0116
Confidence level	< 95%		< 95%		99%		< 95%

The George area shows the opposite effect, although not very uniformly. This is apparent from the positive correlation (r = + 0,3909). The highest forest incidence of 7,2% is in protected kloofs at altitudes exceeding 600 metres. The Knysna forest area shows a very similar trend to the regional effect. Linear regression shows low correlation in this case, and it is expected that curvilinear regression analysis would be more apt, comparable to the regional effect (Fig. 33) discussed earlier.

6.2.8 Rural Settlement

The effect of the rural settlement pattern on the forest location pattern is fairly homogenous in the George and Knysna forest areas corresponding to the regional trend. This is evident by the highest relative forest cover percentage in the unpopulated factor type (Table 47), and also by relatively equal correlative trends (r- and t-values). The Tsitsikamma shows an insignificant treatment effect with most of the percentage forest cover values lying close to the mean of 13,8%.

TABLE 47 THE EFFECT OF RURAL SETTLEMENT ON FOREST COVER

FACTOR	FOREST COVER						
SETTLEMENT (*BUILDINGS)	GEORGE AREA		KNYSNA AREA		TSITSIKAMMA AREA		SOUTHERN CAPE
	%	Angles	%	Angles	%	Angles	%
0	5,2	13,18	21,0	27,27	11,8	20,09	15,7
1 - 5	4,9	12,79	18,9	25,77	25,8	30,53	17,6
6 - 10	3,5	10,78	18,1	25,18	12,2	20,44	12,1
11 - 20	1,8	7,71	19,8	26,42	12,8	20,96	13,0
21 - 30	0	0	11,9	20,18	13,5	21,56	8,8
31 >	0,4	3,63	10,4	18,81	14,5	22,38	7,5
Mean forest cover	3,6%		19,6%		13,8%		14,7%
r-value	- 0,9001		- 0,9178		- 0,2287		-0,9426
t-value	- 4,1317		- 4,6237		- 0,4699		-5,6460
Confidence level	95%		99%		< 95%		99%

* Number of buildings are indicated per unit square of one minute by one minute = 282 ha.

6.3 Summary of the Effects of Variables on Forest Cover in Local Areas

Some variables, such as macro-terrain and altitude in the George Mountain Forest Area (Tables 40 and 47), reveal distinctly contradictory treatment trends when compared to the other two local areas and the region as a whole. In other variables differences in treatment appear less distinct. The variation of each of the factor effects is probably best revealed by the results of the significance tests.

In the George Mountain Forest Area only the treatment of rainfall proved significant to a 99% confidence level (correlation coefficient of 0,9149), while that of macro-terrain (correlation coefficient of -0,9519) and rural settlement (correlation coefficient, i.e. c.c. = 0,9001) proved significant to a 95% confidence level. The treatments of geology, aspect, micro-terrain and altitude all proved to be significant at the 95% level.

In the Knysna Forest Area the treatments of macro-terrain (c.c. = - 0,9934), rainfall (c.c. = 0,9818), geology (c.c. = 0,9881), micro-terrain (c.c. = - 0,9315), aspect (c.c. = - 0,9810) and rural settlement (c.c. = - 0,9178) all proved significant to a 99% confidence level, while that of altitude remained insignificant.

In the Tsitsikamma Forest Area the treatment of altitude (c.c. = - 0,9748) proved highly significant to a 99% confidence level, with that of macro-terrain (c.c. = - 0,9278), rainfall (c.c. = 0,8179) and geology (c.c. = 0,9562) significant to a 95% confidence level.

One general shortcoming with the statistical analysis summarised above, is the fact that on average each variable was only tested at six levels. Nevertheless the treatments clearly indicate the very significant effects of variables on forest cover in the Knysna forest heartland, with lesser effects in the Tsitsikamma and George areas.

6.4 Selection of Variables

The selection and plotting of variables was conducted in the same way as that described for the Regional Factorial Analysis (section 5.4.2). This means that each factor was treated at two levels only, a so-called positive and a negative value level, although with a difference. The criterion for dividing each of the factors was the local mean percentage forest cover, i.e. 3,6% for the George Mountain Forests, 19,6% for the Knysna Forests and 13,8% for the Tsitsikamma Forests (Table 39). Furthermore, as indicated under par. 5.4.1, the eight factors concerned were divided into two Factor-groups, the so-called Group A-factors (macro-terrain, rainfall, geology and accessibility) with their expected regional trend; and the Group B-factors (micro-terrain, aspect, altitude and rural settlement) which were expected to feature detail of a more local nature.

6.4.1 The Group A-factors

The four Group A-factors, which all already featured in the regional factorial analysis, were represented as follows:

6.4.1.1 Macro-terrain Type

George Mountain Forests:
From Table 40 it is evident that only level terrain features below-average forest cover, namely 2%. All four steeper terrain types feature a higher forest cover than the local average of 3,6%.

The dividing line in this case is therefore clearcut, a negative forest cover below 5° slope, and a positive cover above this figure. Level terrain covers 54% of the George study area and 29% of indigenous forests.

Knysna Forests:
The Knysna forests show a reverse tendency to the George Mountain Forest trend (Table 40). Level terrain features above-average forest cover of 25,1%, while the gentle slopes are approximately average at 19,0%. The other three terrain types feature a very low forest cover. Level and gently sloping terrain represented by 0 to 11° average slope, therefore represent the positive criterion, the steeper slopes featuring as the negative value. Level and gently sloping terrain covers 80% of the Knysna land area and 91% of its forests.

Tsitsikamma Forests:
With an average forest cover of 13,8%, the Tsitsikamma forests reveal a very similar trend to that of the Knysna forests, level terrain featuring an above-average forest cover of 21,2%, while the gentle foothills are average at 13,7%. Eleven degrees average slope is therefore again the dividing line between positive and negative effect values. The two categories together cover 74% of the total land area and 91% of the total forested area.

6.4.1.2 Rainfall

From Table 41 it is evident that the effect of rainfall on forest cover in the three local study regions differs widely in the marginal

601 mm - 800 mm annual rainfall categories. The George area reveals above-average forest cover of 4,8% in the 601 - 700 mm range, but a below-average 1,5% cover from 701 - 800 mm, before rising out above average with rise in rainfall. The Knysna area features above-average forest cover beyond 801 mm rainfall, while the Tsitsikamma features above-average forest cover of 19,8% between 701 - 800 mm and thereafter only again beyond 1 001 mm rainfall. It was decided to rather standardise the rainfall factor in all three study regions to a negative value below 700 mm, and a positive value of above 701 mm annual rainfall. In the George mountain region 46% of the total land area lies in the below 700 mm range, while 27% of the forests are located therein; in the Knysna forests this negative value covers 26% of the land area but only 1% of the forests; in the Tsitsikamma forests only 14% of the land area receives less than 700 mm rainfall and also only 1% of the forests.

6.4.1.3 Geology

From Table 47 it is evident that the shales and sandstones are on the whole more heavily forested than any of the remaining geological formations. Two noteworthy anomalies occur though. In the Knysna forest area the Bokkeveld shales are located on very steep and dry slopes and have virtually no forest cover (0,3%). These shales however only cover 5,8% of the Knysna forest study area. In the Tsitsikamma area Table Mountain sandstone features below-average forest cover. However 72% of the forests grow on TMS (Table 42). In this case the unforested part is associated with very steep slopes with a very thin soil cover. It was decided to divide each local study area into: all shale and sandstone deposits as a positive cover value, based on the above-average forest cover values of 16,0%, 21,6% and 21,3% respectively for TMS, Malmesbury shales and Bokkeveld shales, and to apply a negative valuation on all other formations.

The George mountain forests feature shale and sandstone in the northern and eastern high rainfall areas. These cover 51% of the local study area, essentially situated on shales and sandstone. The latter cover 83% of the total area concerned and 92% of the forests. Of the Tsitsikamma area 96% is located on TMS and Bokkeveld shale. These support 98% of the forests.

6.4.1.4 Accessibility

In the George and Knysna forests the accessible areas have a fairly distinct below-average forest cover of 2,3% and 17,5% respectively (Table 43). These areas represent respectively 71% and 52% of the total land areas involved and respectively 46% and 47% of the indigenous forests. The Tsitsikamma forests follow an altogether reverse trend. Here the inaccessible areas feature below-average forest cover of 9,0%. The inaccessible areas cover 65% of the total land area and 43% of the forests concerned. It is therefore evident that the positive forest cover value is to be applied to the inaccessible areas in the George and Knysna areas and to the accessible areas in the Tsitsikamma.

The selection of the above four factorial levels means that the Knysna forest area was to be statistically tested at the same levels as the earlier regional study of the Southern Cape as a whole. The Tsitsikamma forests differed from the regional study in the reverse application of the accessibility factor. The George forest area, again, differed by the reverse application of the macro-terrain factor.

6.4.2 The Group B-factors

The delimitation of the Group B-factors was more detailed than the broader representation of the Group A-factors. Each factor was however again only described at two levels.

6.4.2.1 Micro-terrain

Table 44 shows the plains and the very steep mountain slopes of the George area to be fairly denuded of forest. Eighty-seven per cent of the forests are located within the 3,5° to 26,4° delimitation, which represents 47% of the George mountain forest area. In the Knysna forest area the plains and the steeper terrain feature below-average forest cover. The gentle and moderate slopes from 3,5° to 10,5°, which represent 43% of the area and 65% of the forests, features as the positive forest cover value. In the Tsitsikamma the foothills to steeper mountain zones feature below-average forest cover. The positive forest cover value lies within the 0 to 10,5° average slope range. The latter represent 56% of the total area and 86% of the forests therein.

6.4.2.2 Aspect

From Table 45 the positive level in the George mountain forest area are the southerly, easterly and westerly-facing slopes, each featuring above-average forest cover. The three aspect types together cover 43% of the area concerned and 90% of the forests.

A similar delimitation is evident in the Knysna region, where southerly, easterly and westerly slopes respectively have forest covers of 23,1%, 21,3% and 21,1%. These together cover 60% of the land area concerned and 68% of the forests.

The Tsitsikamma pattern is different. The positive forest cover value has decidedly shifted to south-facing and level terrain, with westerly, northerly and easterly slopes, the negative level, covering 36% of the area and only 21% of the forests.

6.4.2.3 Altitude

Table 46 reveals a fairly distinct trend of an increase in forest cover with altitude from east to west. In the Tsitsikamma above-average forest cover values are evident from 0 - 300 metres. The latter covers 46% of the land area and 80% of all the forests concerned. In the Knysna area the positive value ranges from 0 - 450 metres, which represent 61% of the land area concerned and 85% of the forests. The George mountain forests reveal a somewhat irregular pattern, the highest forested level being above 600 metres, namely 7,2%. This is followed downwards by a below-average forest cover of 1,5% from 451 - 600 metres, above-average cover of 6,5% from 151 - 300 metres, and a marginal 3,2% forest cover at the lowest altitude level, 0 - 150 metres (Table 46). It was decided to ascribe a positive forest cover value to areas in excess of 300 metres. This area comprises 34% of the total local study region, and 58% of the forests. This choice obviously excludes the coastal forests, evident south of George (Fig. 6), and thereby emphasises the mountain forest trend.

6.4.2.4 Rural Settlement

From Table 47 the effect of the Rural Settlement pattern is fairly definitely defined. In the George mountain forest area, the fairly unpopulated areas from nil to ten buildings per 282 ha surface area features a positive forest cover value. The area involved represents 70% of the local study area and 92% of the forests. In the Knysna forest area, the tendency of deforestation with population pressure, already appears somewhat weakened. Ninety-three per cent of the area and 96% of the forests are located on land with a settlement from nil to twenty buildings per 282 ha. In the Tsitsikamma forests the populated areas, featuring areas with one or more buildings per 282 ha surface area, reveal average or above-average forest cover. Forty per cent of the forests, located on 29% of the area, represent this rural settlement type.

6.4.3 Summary of Variables

Table 48 summarises the factorial effects discussed in the previous paragraphs and is self-explanatory.

6.5 Factorial Analysis of Local Areas: Plotting the Variables

Boundaries for the four Group A-factor levels had already been drawn on the standard 1 : 250 000

TABLE 48 SELECTION OF VARIABLES : SUMMARY OF FACTORIAL EFFECTS

FACTORIAL TYPE	GROUP FACTORS	LOCAL AREA	POSITIVE VALUE	NEGATIVE VALU
A. Macro-terrain	A	George	> 5° slope	< 5° slope
		Knysna	0 - 11° slope	> 11° slope
		Tsitsikamma	0 - 11° slope	> 11° slope
B. Rainfall	A	George) Knysna) Tsitsikamma)	> 700 mm	< 700 mm
C. Geology	A	George) Knysna) Tsitsikamma)	Shales and sandstones	Other formations
D. Accessibility		George) Knysna)	Inaccessible	Accessible
		Tsitsikamma	Accessible	Inaccessible
A. Micro-terrain	B	George	3,5 - 26,4° slope	0 - 3,5° slope and > 26,4°
		Knysna	3,5 - 10,5° slope	0 - 3,5° slope and > 10,5°
		Tsitsikamma	0 - 10,5° slope	> 10,5° slope
B. Aspect	B	George	S. E. W.	N. L.
		Knysna	S. E. W.	N. L.
		Tsitsikamma	S. L.	N. E. W.
C. Altitude	B	George	> 300 m	< 300 m
		Knysna	< 450 m	> 450 m
		Tsitsikamma	< 150 m	> 150 m
D. Rural Settlement	B	George	< 10 buildings	> 10 building
		Knysna	< 20 buildings	> 20 building
		Tsitsikamma	> 1 building	< 1 building

scale map for the regional analysis. Since there was little change in the factorial delimitation in the local areas, Fig. 37 was used per se for the Knysna study area, the regional and local factor levels being the same. For the Tsitsikamma forest area the only change represented an interchange between the positive and negative accessibility levels. In the regional analysis the inaccessible areas were attributed a positive valuation, while in the local study this area received a negative value. The factorial delimitation map for the Tsitsikamma forest area is therefore also not reproduced here. The George mountain forest area however shows a marked difference in the important macro-terrain factor at the local level. Fig. 40 shows the factorial delimitation, which differs from that shown in Fig. 37.

Boundaries were also drawn for the four Group B-factors on three separate maps. Fig. 41 features the factorial analysis of the George mountain forests, Fig. 42 and Fig. 43 respectively of the Knysna and Tsitsikamma forests. Each sector was classified into the 16 possible factor combination types, i.e. abcd, abc, ad, etc., with "I" as a negative value for all four factors. The forest cover was thereafter determined for each factor-combination type in the conventional way by superimposition on the Forest Distribution Map and the Forest Distribution Control Map (Fig. 6 and Fig. 7). The results of this analysis appear on Table 49. Percentage forest cover data was converted to angular units via standard conversion tables, the angular transformations being used for the variance analysis.

The Group B factorial maps (Figs. 41, 42 and 43) show clearly why only four factors could be accommodated in each analysis. Fig. 42 of the Knysna area in particular shows such an intricate maze of intersecting lines, that the factor combinations could only be differentiated by very detailed study on the large-scale base map (1 : 250 000) not shown here. Table 49 provides the results of the areal enumeration and classification of all land and forest cover into the 16 possible combinations, separately for groups A and B.

The overall trend appears to be that the choice of factorial divisions between the relative positive and negative effects was not critical enough. This is borne out by the fact that all land, with the exception of certain portions within the George area, is explained by one or more of the eight factors (Table 49), although only 14,68% of the total land is covered by forest. It is felt that the factorial effects would possibly have been better balanced and more expressive had each factorial division (positive effect) been devised to cover not more than about 50% of the total land area.

The George mountain area reveals a favourable factorial balance, averaging 44% for the eight factors concerned, viz:

Group A Factors

a : covers 45% of the land, b = 54%, c = 51%, d = 28% and I (no effect) = 22% (all being directly calculated from the "percentage of area" column of Table 49). These four factors explain all the forests since "I" features no forest cover.

Group B Factors

a = 47%, b = 33%, c = 44%, d = 50% and I = 36%. All but 4,8% of the forests of this area are explained by the Group B factors.

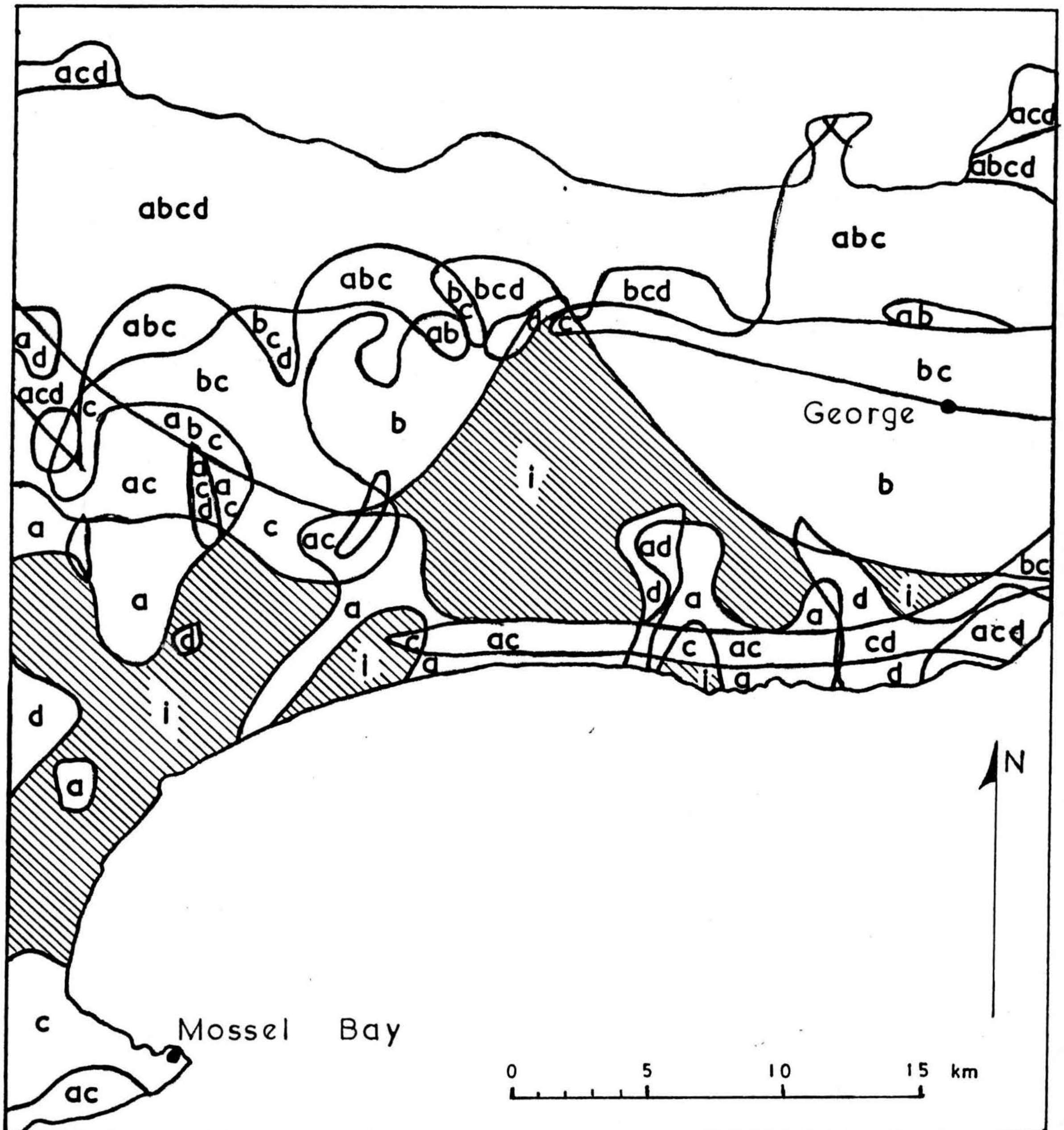
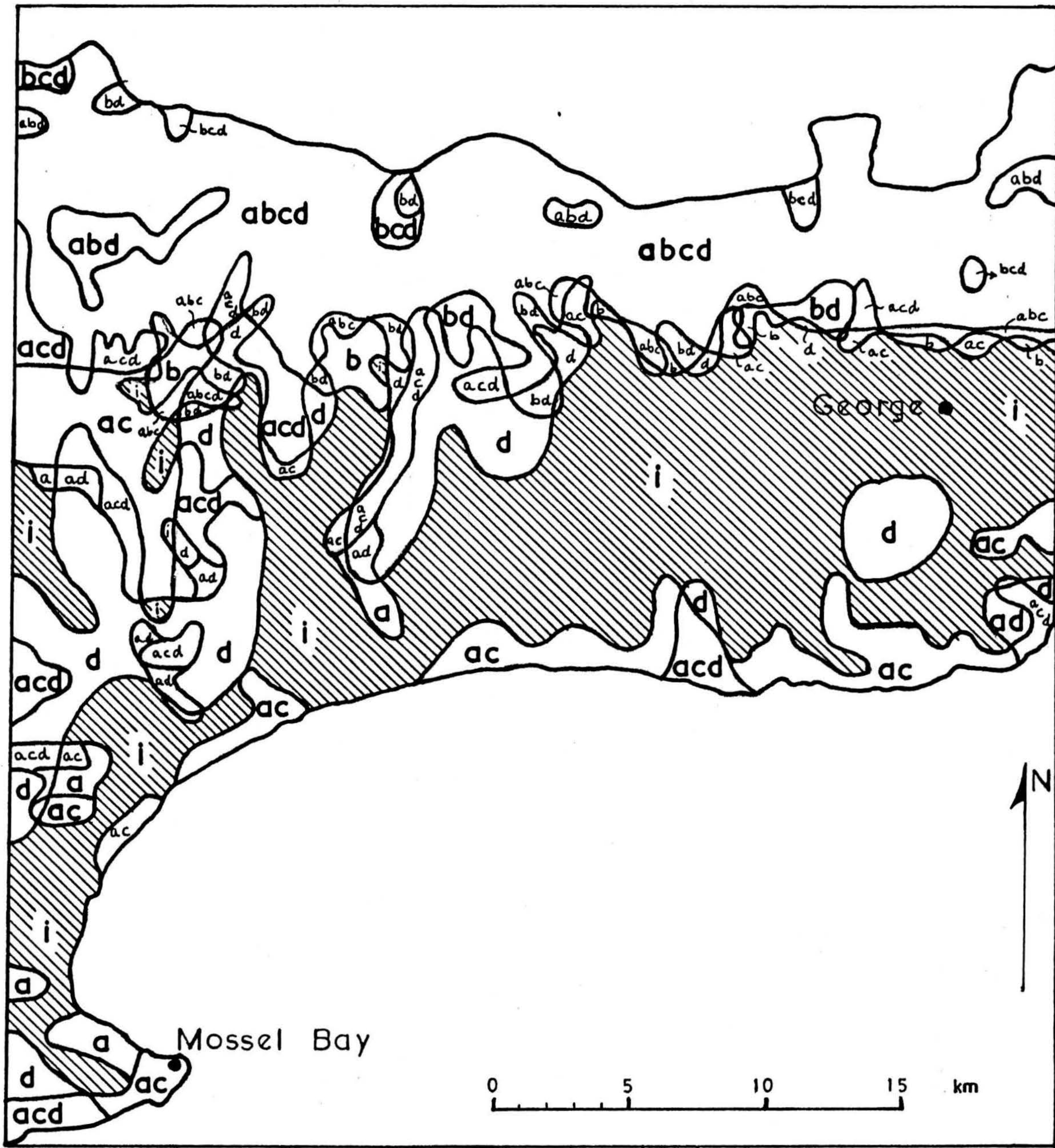


Fig. 40 Group A factorial combinations in the George mountain forests.

a	Macro-terrain
b	Rainfall
c	Geological formation
d	Accessibility
e	No factorial effect



a	Micro-terrain
b	Aspect
c	Altitude
d	Rural settlement
i	No factorial effect

Fig. 41 Group B factorial combinations in the George mountain forests.

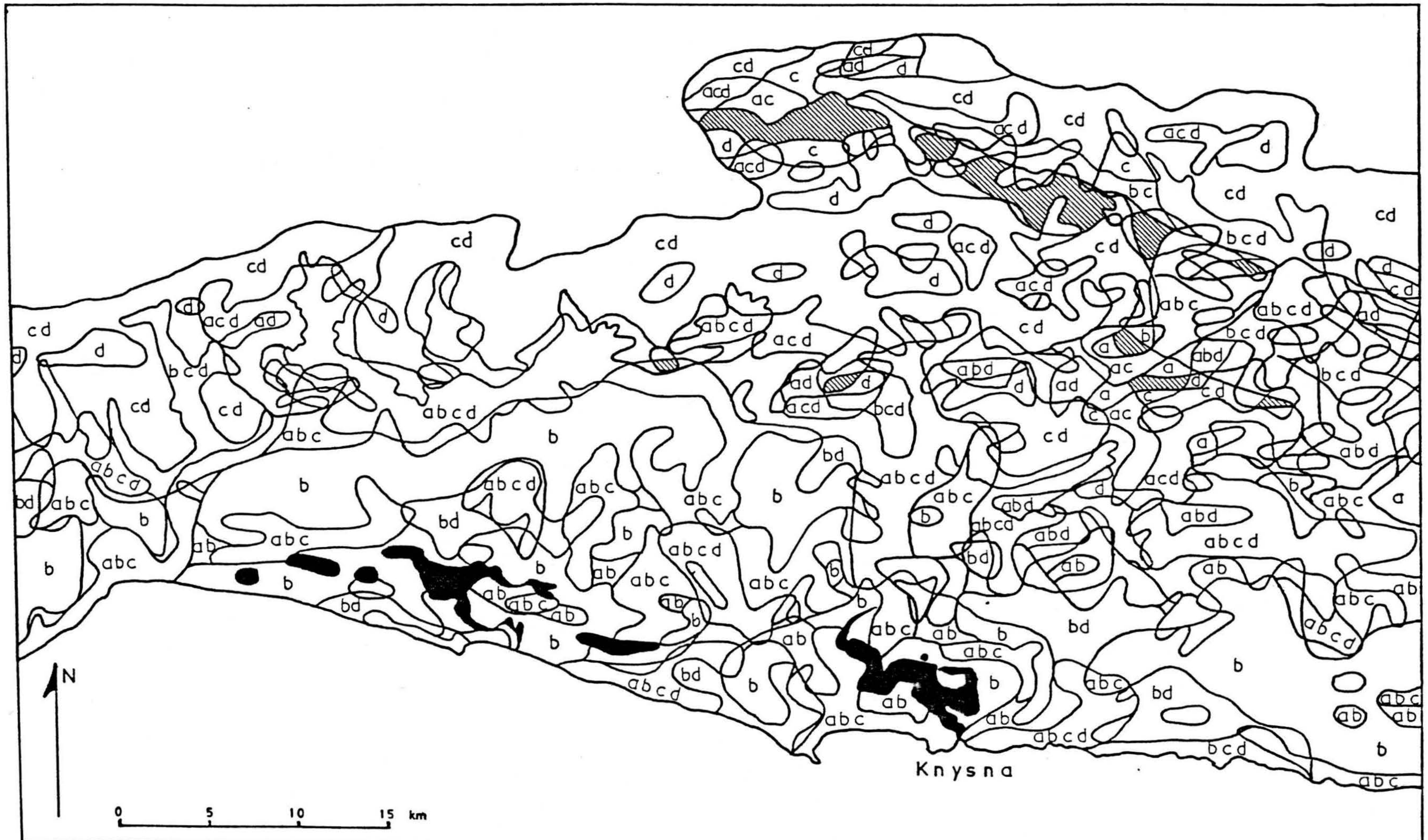


Fig. 42 Group B factorial combinations in the Knysna forest area.

a	Micro-terrain
b	Aspect
c	Altitude
d	Rural settlement
(hatched)	No effect (i)

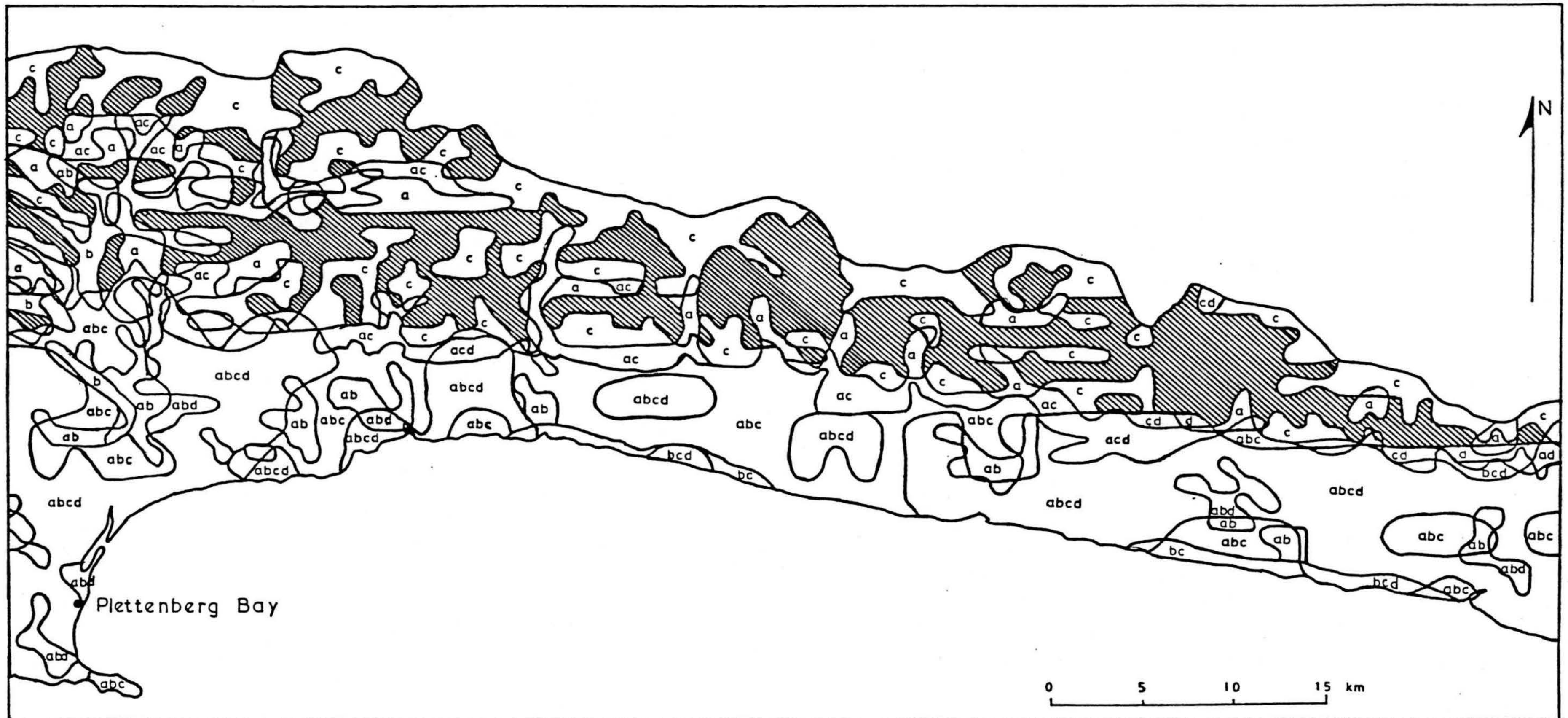


Fig. 43   Group B factorial combinations in the Tsitsikamma forest area.

a	Micro-terrain
b	Aspect
c	Altitude
d	Rural settlement
	No effect (i)

TABLE 49 FACTORIAL ANALYSIS : GROUP A AND B FOUR-FACTOR COMBINATION : LOCAL ANALYSES

FACTOR COMBINATION	GEORGE MOUNTAIN FORESTS						KNYSNA FORESTS						TSITSIKAMMA FORESTS					
	Group A-factors			Group B-factors			Group A-factors			Group B-factors			Group A-factors			Group B-factors		
	% of Area	% Forest Cover	Angles	% of Area	% Forest Cover	Angles	% of Area	% Forest Cover	Angles	% of Area	% Forest Cover	Angles	% of Area	% Forest Cover	Angles	% of Area	% Forest Cover	Angles
abcd	18,5	6,3	14,5	25,4	7,7	16,1	24,9	34,4	35,9	14,2	51,8	46,0	26,5	26,8	31,2	22,0	19,3	26,1
abc	9,4	6,4	14,6	0,9	13,9	21,9	26,6	28,3	32,1	11,8	34,2	35,8	37,6	14,3	22,2	12,9	34,1	35,7
abd	0,6	0,0	0,0	1,7	0,0	0,0	2,2	27,4	31,6	3,6	26,8	31,2	0,5	5,0	12,9	2,7	29,0	32,6
ab	0,9	4,8	12,7	-	-	-	10,0	9,4	17,9	3,3	15,5	23,2	-	-	-	3,8	29,3	32,8
acd	2,3	9,5	17,9	7,6	7,8	16,2	5,1	0,6	4,4	6,7	13,6	21,6	0,5	5,0	12,9	2,1	19,4	26,1
ac	5,2	5,8	13,9	9,3	6,4	14,7	5,9	0,5	4,1	2,0	15,5	23,2	4,2	0,0	0,0	5,1	17,5	24,7
ad	1,3	6,4	14,6	1,1	3,7	11,1	0,6	0,0	0,0	1,4	12,4	20,6	3,4	5,1	13,1	0,4	0,0	0,0
a	7,0	2,5	9,1	1,3	0,0	0,0	4,6	1,8	7,7	1,2	4,1	11,7	-	-	-	5,1	4,4	12,1
bcd	2,2	15,4	23,1	0,8	0,0	0,0	9,0	13,4	21,5	5,1	15,6	23,3	3,9	15,9	23,5	0,8	9,4	17,9
bc	8,3	6,2	14,4	-	-	-	1,9	28,0	32,0	0,8	6,3	14,5	16,7	3,1	10,1	1,6	13,9	21,9
bd	0,3	0,0	0,0	2,6	3,3	10,5	-	-	-	6,0	26,9	31,2	-	-	-	0,1	0,0	0,0
b	14,2	0,0	0,0	1,6	0,0	0,0	-	-	-	16,5	9,6	18,1	-	-	-	1,7	8,7	17,2
cd	0,6	22,1	28,0	-	-	-	6,0	0,8	5,1	20,1	4,9	12,8	-	-	-	0,7	3,5	10,8
c	4,4	1,9	7,9	-	-	-	3,2	0,5	4,1	1,1	6,0	14,2	6,7	0,0	0,0	18,0	3,9	11,4
d	2,6	0,0	0,0	11,4	0,4	3,6	-	-	-	4,0	4,8	12,7	-	-	-	0,4	18,8	25,7
I	22,2	0,0	0,0	36,3	0,5	4,1	-	-	-	2,2	0,7	4,8	-	-	-	22,6	2,2	8,5
	100%		100%		100%		100%		100%		100%		100%		100%		100%	

The Knysna area averages a 64% "positive" factorial land cover (percentage values for the Group A and B factors in a, b, c and d sequence respectively being 80, 75, 83, 48, 44, 61, 62 and 61). About 0,1% of the indigenous forests of this local area remain unexplained.

The Tsitsikamma averages 60% "positive" factorial land cover effect (percentatge values in normal sequence being 73, 85, 96, 35, 54, 46, 58 and 29). About 3,6% of the forests thereby remain unexplained.

Percentage forest cover (Table 49) was again converted to angles via standard conversion tables.

6.6 Multi-variance Analysis

Analysis of the results in Table 50 was carried out using the Standard Yates 2^n procedure (Davies, 1967). This method is the same as that used for the regional analysis (par. 5.4.4). In this case it was used separately for each of the three local study areas, and again for each of the two factorial groups.

Tables 50 and 51 show the results of respectively the Group A and Group B factorial treatments, the higher order three and four factor interactions again providing the error mean square (see also Table 38 for the regional treatment of the Group A factors and Annexure A, which shows the calculations in more detail). In Tables 50 and 51 the respective mean squares of the main factors and their interactions were divided by the error-factor (higher order interactions), the effects thereby being represented by F-values. An exception was made on error variance with the factorial effects of Group B factors in the Tsitiskamma study area (Table 51). Here the very apparent high interaction between micro-terrain (a) and altitude (b) caused the error mean square to be calculated by the variance of all interactions and higher order interactions except the ab-combinations, i.e. acd, ac, ad, bcd, bc, bd and cd (refer to Annexure A, Table A12). The validity of the calculation of such an error variance factor is fully discussed by Davies (1967, p. 278 and Appendix 7D).

TABLE 50 MULTI-VARIANCE ANALYSIS OF GROUP A FACTORIAL EFFECTS ON FOREST COVER

NATURE OF EFFECT	SOURCE	EFFECT (F-value)		
		George	Knysna	Tsitsikamma
Main factors	Macro-terrain (a)	2,5	8,4 *	16,4 **
	Rainfall (b)	0,6	35,4 **	26,0 **
	Geology (c)	42,2**	11,2 *	26,0 **
	Accessibility (d)	2,9	0,0	17,9 **
Interactions	ac	10,5*		
	cd	7,0*		
	bc			26,3 **
Higher order interactions	abc, abd, acd, bcd, abcd	Error	Error	Error

* = 95% confidence level; ** = 99% confidence level

6.7 Interpretation and Discussion of Results

On the whole, the results of the multi-variance analysis in Tables 50 and 51 show that the factorial effects have evidently warranted the division of the Southern Cape region into three local areas. This is borne out by comparisons between the impacts of main factors and of interactions of factors on forest cover in each of the three sub-regions.

In the Knysna forest 'heartland' area forest cover appears fairly directly explained by the impact

TABLE 51 MULTI-VARIANCE ANALYSIS OF GROUP B FACTORIAL EFFECTS ON FOREST COVER

NATURE OF EFFECT	SOURCE	EFFECT (F-value)		
		George	Knysna	Tsitsikamma
Main factors	Micro-terrain (a)	11,9 *	19,5**	17,0 **
	Altitude (b)	0,0	30,2**	12,2 *
	Aspect (c)	4,9	4,2	6,1 *
	Rural settlement (d)	0,9	8,5*	1,8
Interactions	ac	18,0**	5,1	
	ab			11,8 *
	abc	-	-	17,1 **
	abcd	-	-	8,4 *
Higher order interactions	abc, abd, acd, bcd, abcd	Error	Error	-
All interactions and higher order interactions except the ab-combinations		-	-	Error
* = 95% confidence level; ** = 99% confidence level				

of the main factors, with little to no effect by the interactions of factors on one another. In fact six of the eight factors tested show a significance level of the main factors in excess of 95% confidence level. In the George area the effect of the interactions of factors on one another become more pronounced, while in the Tsitsikamma the impact of both main factors and those of interactions prove highly significant, more so than in the Knysna heartland and the George area. It is suggested that the reason for the progressively higher factorial effects from west to east lie closely associated with respectively the narrowing of the mountain to coastal shore-line distance. Each of the three sub-regions is interpreted separately below.

6.7.1 The George Mountain Forest Area

From Table 50 which features the Group A factors, the effects on forest cover of geological formations (factor c) and the interactions between geological formations and respectively macro-terrain (ac) and human accessibility (ad), prove to be highly significant (95% confidence level). Probably equally important is the relative insignificance of the factor rainfall (factor b), which features as highly significant in the Knysna and Tsitsikamma areas.

From statistics mentioned earlier, the effects of geology, terrain type and human access are briefly reviewed individually. Fifty-one per cent of the George study area consists of "positive" sandstone and shale formations (factor c) and 93% of the forests concerned are located thereon (Table 42). As far as terrain type (factor a) is concerned, 81% of the forests are located on steeper terrain (above 5° average slope). This terrain classification covers 46% of the local study area (basic data for Table 40). The inaccessible deeper, more protected river valleys and steeper mountain slopes (factor d), cover 29% of the George study area and features 54% of the forests (basic data for Table 43).

The rather restricted forest location pattern in this western study sector is thereby explained by lack of sufficient rainfall along the plains and coastline, as a result of which the remnant forests occur on an admixture of colluvated, moisture-retaining Table Mountain sandstone with a shale/schist soil admixture, located along the more inaccessible river depressions and foothill to steeper mountain zone. But particularly this steeper terrain appears to harbour a yet unexplained soil element. This is thought to range from "no soil cover" along extensive portions of the steeper TMS slopes, mainly on the coarser Peninsula sandstone, to soil-depth restrictions, such as ferri- and silcretions, evident below the foothills. Lack of suitable soil depth and very coarse, deeply weathered and unstructured parent rock along the plains, with resultant rapid moisture drainage, explain much of the unforested area.

In the analysis of the Group B factors (Table 51) the effects of terrain (factor a) and that of the interaction between terrain and aspect (ac) prove to be significant. The results of this treatment thereby broadly substantiate conclusions reached with the analysis of the Group A factors, namely that the forests have an affinity for the cooler and moister south/east/west-facing slopes, both along parts of the coast and the more inland mountains, as well as for the more rugged river incisions into the plains. These incisions mainly account for the eastern and western aspects, while the foothills are usually south-orientated. According to basic data calculated for compiling Table 44, 47% of the George land area is classified into the "positive" 3,5° to 26,4° average slope category. This area features 81% of the forests. Southern, eastern and western aspects represent only 43% of the total area concerned (basic data for Table 45), but account for 90% of the forest area. All forests are thereby explained in this study area (Table 49).

6.7.2 The Knysna Forest Area

In the treatment of the Group A factors, the effect of rainfall is highly significant (99% confidence level), while the effect of both geological formations and terrain types are significant to 95% confidence level (Table 50).

The effects of the above main factors are well illustrated by reference to percentage land area and forest area covered by each of the factors concerned. Ninety-nine per cent of the forests in the Knysna area occur on land receiving annual rainfall above 701 mm. Seventy-four per cent of the land area concerned receives such a rainfall. Eighty-three per cent of the Knysna area lies on TMS and shales, on which 92% of the forests occur. Eighty per cent of the Knysna area is located on the plains and lower foothills from 0 to 11° average slope, and 91% of the Knysna forests occur thereon.

Among the Group B factors altitude shows the most significant effect. Sixty-two percent of the region lies below 1 500 feet (450 m), so do 85% of the forests. The more rugged plains and foothills (3,5° to 10,5° average slope) cover 43% of the study area and account for 66% of the forests. The rural settlement pattern is perhaps somewhat misleading, because 93% of the Knysna land area is represented by a positive value, representing 96% of the forests.

Summarising the treatment effects, the Knysna forests are located on land with an annual rainfall exceeding 701 mm; they are located along the lower foothills below an elevation of about 450 m; they are located on sandstone and shale sediments and have persisted in a moderate to dense rural environment. The forests are fully explained by this treatment.

6.7.3 The Tsitsikamma Forest Area

Both the Group A and B factorial effects on the Tsitsikamma forest location pattern appear uniformly highly significant, except for the effect of rural settlement. This pattern was to be expected though, because the Tsitsikamma area is very sharply divided between a level plateau and steeply rising foothills and mountains. Among the Group A factors the high significance levels of the effects of rainfall and geological formations and the equally high significant interaction between these two factors (ab) is an outstanding factor stressing orographic rainfall impact. Of perhaps greater significance is the extremely high significance level of the ab-interactions among the Group B factors (micro-terrain and altitude). This interaction necessitated the error variance to be based on all the interactions except for all the ab-combinations. The forests in this study area are essentially located along the plains and lower slopes, at low elevation; located on colluvated sandstone material admixed with shale. The very strong interactions between rainfall and geological formations (Group A factors) and between micro-terrain, elevation and aspect (Group B factors) evident from Tables 50 and 51 indicate that the forest location pattern is explained by a large number of factors and interactions between them. It is not regarded necessary to pursue the effects of each of the factors for the Tsitsikamma forests at this stage, since the factorial effects fully describe the forest location pattern.

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CHAPTER 7

PREDICTING THE POTENTIAL FOREST AREA BY FACTORIAL COMBINATION DESIGNS

The idea of combining already arose with the decision to separate the factors into the two A and B treatment groups. There was, however, another reason for attempting such combination, namely to attempt to predict the potential or former areal pattern of the forests. Haggett (1968, pp. 321 - 324) used regression relationships for combination designs, in what he termed "residual mapping" to determine predicted forest cover levels. In the study of the Southern Cape forests such a study was thought necessary for the following purposes:

To determine to what extent the eight chosen factors would indicate a pattern larger than the existing forest perimeter;

to attempt to explain why certain potentially forestable areas are nowadays bare of forest;

to determine which factors other than the eight selected ones, could possibly be identified to explain any anomalies.

Since the combination method was based on an entirely new experimental design, it was only applied to the George mountain forest area, and not to Knysna and the Tsitsikamma. The choice for the George area was deliberate, mainly because:

of its relatively small size;

of fairly balanced factorial effects, which were less dominated by rainfall than the other local study areas;

of the fairly extensive non-classified "I" contingency, which appeared far more weakly in the Knysna and Tsitsikamma areas (Table 49);

in this area the impact of man on the forest location pattern has been most severely tested, the forests representing the remnants after such impact.

7.1 Establishing a Basis for a Combination Design

For the purpose of combining the two factorial groups, which together represent eight factors, a pattern had to be devised which would accommodate results of both analyses with a fair measure of validity. It is on this point of validity, that the application of the deterministic method of data collection, used in this treatise, became a helpful aid. The deterministic approach implies that data collected for the eight factors is complete with no sampling error to contend with. Data collected in this way and expressed in direct measurement terms, lend themselves better for statistical projections of this kind than factorial data which is indirectly represented by indexes and collected on a sampling basis. The latter factorial expression is common to multiple regression analysis.

For the purpose of determining the most suitable combination design, three different methods were explored:

(a) The super imposition of the two factorial combination maps, i.e. Fig. 40 for the four Group A factors with Fig. 41 for the four Group B factors. The result would thereby provide a combination effect of all eight factors. This method was however found to be not only unpractical, but prohibitively complex, because of the highly involved maze of combinations, with theoretically 256 factor combination possibilities. A second consideration for discarding this method of analysis lay in the fact that neither the result of the simple regression analysis of the individual factors nor those of the multi-variance analysis would thereby be incorporated.

(b) The basis for the second method considered lay in utilising the results of the simple regression analysis for each of the eight factors, by using the correlation coefficient (r-values) and the significance levels (t-values) as criteria. The application of this method would imply that figure values be alloted to those "positive" factorial effects (meaning above-average forest cover), that proved to be statistically significant. However, the regression analysis in this study was based on testing factorial effects on forest cover at an average of five levels only, so that this method did not appear justifiable.

(c) The second method referred to above, nevertheless led to the design actually used. This was based on the results of the multi-variance analysis of the Group A and Group B factorial treatments. The significance values (F-values) attained in the treatments were accorded figure values on the following basis:

99% confidence level = figure value of three
95% confidence level = figure value of two
90% confidence level = figure value of one

The above values were applied to treatment results of both the main factors and to interactions, e.g. if a main factor "a" was statistically significant to 99% confidence level and the interaction "ac" to 95% c.l., then the combinations abc, acd and ac would all be accorded values of five (three for the "a" plus two for the "ac" interaction).

7.2 Factorial Value Allocation

The values of three, two and one, accorded respectively for 99%, 95% and 90% confidence levels (F-values), were now applied to the A and B factorial treatments of the George mountain forests (Annexure A, Tables A2 and A4 provide full details, while Tables 50 and 51 show summaries thereof). Table 52 shows the direct value allocation accorded to main factors and factor combinations concerned.

TABLE 52 DIRECT VALUE ALLOCATION TO GROUP A AND B FACTORS : GEORGE MOUNTAIN FORESTS

MAIN FACTORS AND FACTOR INTERACTIONS	DIRECT VALUE ALLOCATION	
	Group A Factors	Group B Factors
a	-	2
c	3	1
ac	2	3
ad	1	-
bd	1	-
cd	2	-

The direct value allocation (Table 52) was hereafter applied to all the possible treatment combinations for a total factorial value allocation (Table 53).

The total value effect for each main factor within the factor combination is summarised in Table 54.

TABLE 53 FACTORIAL VALUES FOR GROUP A AND B FACTORS : GEORGE MOUNTAIN FORESTS

FACTORIAL COMBINATION	TOTAL VALUE ALLOCATION	
	Group A Factors	Group B Factors
abcd	9	6
abc	5	6
abd	2	2
ab	0	2
acd	8	6
ac	5	6
ad	1	2
a	0	2
bcd	6	1
bc	3	1
bd	1	0
b	0	0
cd	5	1
c	3	1
d	0	0
I	0	0

The relative high factor values of the Group A factors appear justified, because Group B does not feature a precipitation nor a soil-orientated factor. The relative insignificance of precipitation in Group A (factor b) must be attributed to the low annual precipitation dividing line of 700 mm between the negative and the positive factorial effects (Table 48). The inclusion of both macro-terrain and micro-terrain in the factor combination is probably an over-emphasis of the effect of relief.

7.3 The Identification of Factor Combination Types

As the next step the total value allocation of the different factorial combinations in Table 53 were grouped into distinctive factor combination types, based on progressively lower average combination values, (Table 55). It was decided for this purpose to group together the highest values within both the Group A and Group B treatments and to classify these into a First Order combination. This was followed by a Second Order combination, comprising moderately high values, while the remainder were all grouped into a Third Order combination. Table 55 provides the results of this exercise and is self-explanatory. Both the percentage land area and percentage forest area total 200%. This is brought about by the treatment of both the Group A factors and the Group B factors over the same areas, thereby doubling the percentages.

TABLE 54 SUMMARY OF THE TOTAL VALUE EFFECT OF THE MAIN FACTORS : GEORGE MOUNTAIN FORESTS

FACTORIAL TYPE	FACTOR GROUP	TOTAL MAIN FACTOR VALUE
(a) Macro-terrain	A	30
(b) Rainfall	A	26
(c) Geology	A	44
(d) Accessibility	A	37
(a) Micro-terrain	B	32
(b) Elevation/altitude	B	18
(c) Aspect	B	28
(d) Rural settlement	B	18

7.4 Mapping the Factor Combination Types

The next step involves mapping the factor combination types arrived at in par. 7.3, thereby actually combining the Group A and B factorial treatment into one design. Fig. 44 features the First Order combinations of Group A and B, drawn with Fig. 40 and Fig. 41 as basis. Fig. 45 features the delimitation of the Second Order combinations of the Group A interactions concerned. These were traced from Fig. 40. Fig. 46 features the combination of both these maps, namely Fig. 44 and Fig. 45. Fig. 46 must be regarded as the final combination map. It features six main divisions (Table 56).

Of the George forests, 97,7% are explained by this combination design, but even the 2,3% of forest area in the unclassified division (Table 56; Fig. 46) was identifiable as mainly located along river banks. In a similar study design 99,4% of the Knysna heartland forests were explained. Fig. 46 features the 500 mm annual rainfall isohyet. This line is regarded as an absolute forest delimitation line, since no forests were found to occur in areas with an annual rainfall below 500 mm (Table 23). Fig. 46 was used as basis for drawing a map which features the probable indigenous forest location in prehistoric times, i.e. more than 300 years ago (Fig. 47), under current climatic conditions.

For purposes of compiling this forest probability map, the following criteria were considered:

TABLE 55 FACTOR COMBINATION TYPES : GEORGE MOUNTAIN FORESTS

FACTOR GROUP	FACTORIAL INTERACTIONS	AVERAGE VALUE	ORDER TYPE	PERCENTAGE OF LAND AREA	PERCENTAGE OF FOREST AREA
A	abcd, acd	8,5	First	20,7	37,7
B	abcd, abc, acd, ac	6,0	First	43,2	90,6
A	abc, bcd, cd, ac	5,2	Second	17,4	37,6
B	None	-	-	-	-
A	abd, ab, ad a, bc, bd, b, c, d, I	1,0	Third	61,9	24,7
B	abd, ab, ad a, bcd, bc bd, b, cd, c, d, I	1,0	Third	56,8	9,4
TOTAL				200,0	200,0

TABLE 56 MAIN FACTORIAL DIVISIONS : GEORGE MOUNTAIN FORESTS

FACTORIAL DIVISION	FACTOR GROUP AND ORDER	AVERAGE VALUE	PERCENTAGE OF LAND AREA	PERCENTAGE OF FOREST AREA
1.	A, First with B First	6,8	17,5	36,5
2.	A, Second with B, first	5,6	14,3	32,9
3.	A, First	4,3	3,1	0,0
4.	B, First	3,0	11,5	21,2
5.	A, Second	2,6	3,4	7,1
6.	Unclassified	0,5	50,2	2,3
TOTAL			100,0	100,0

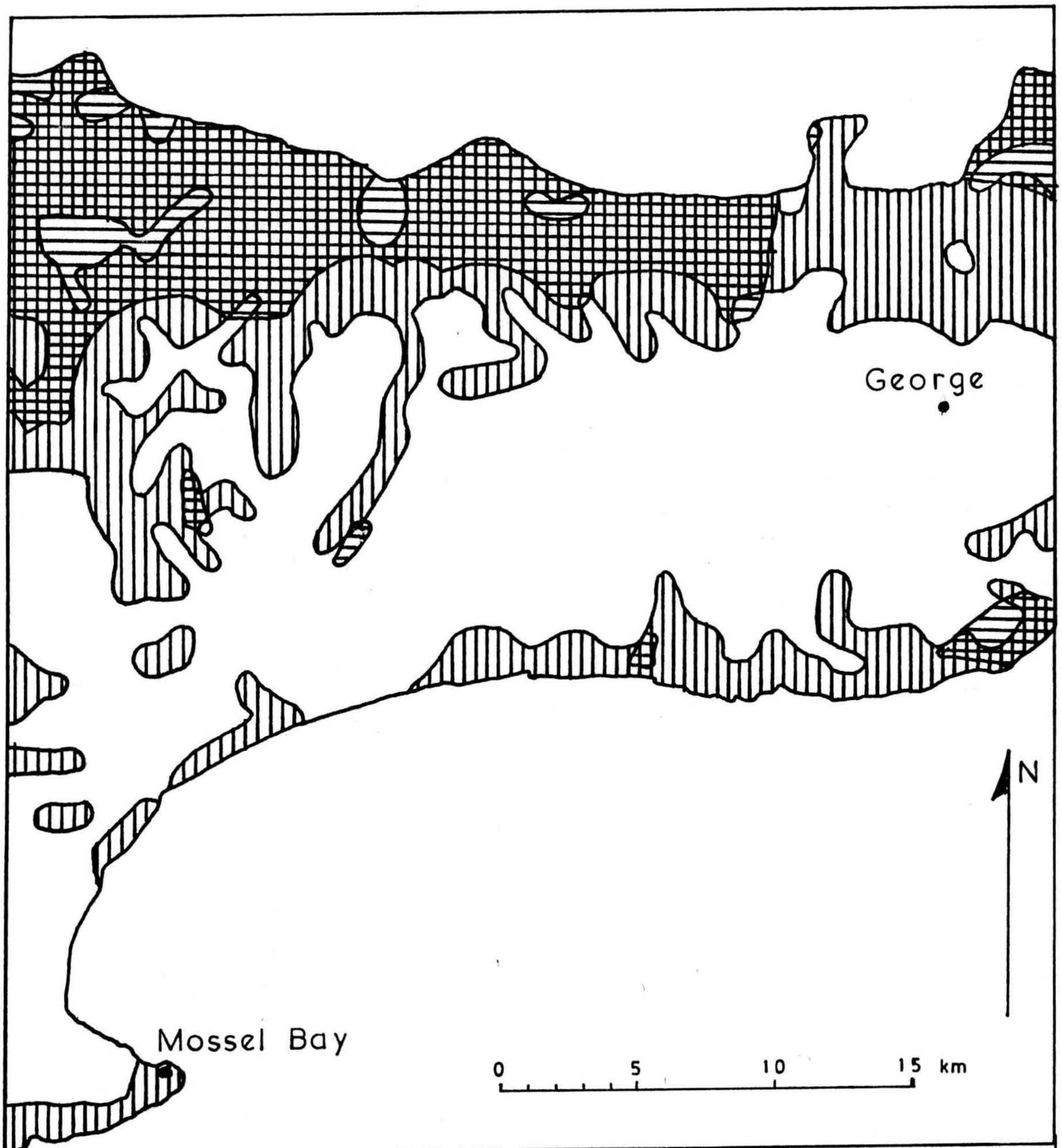

Fig. 44 First-order factor combinations of the George mountain forests.

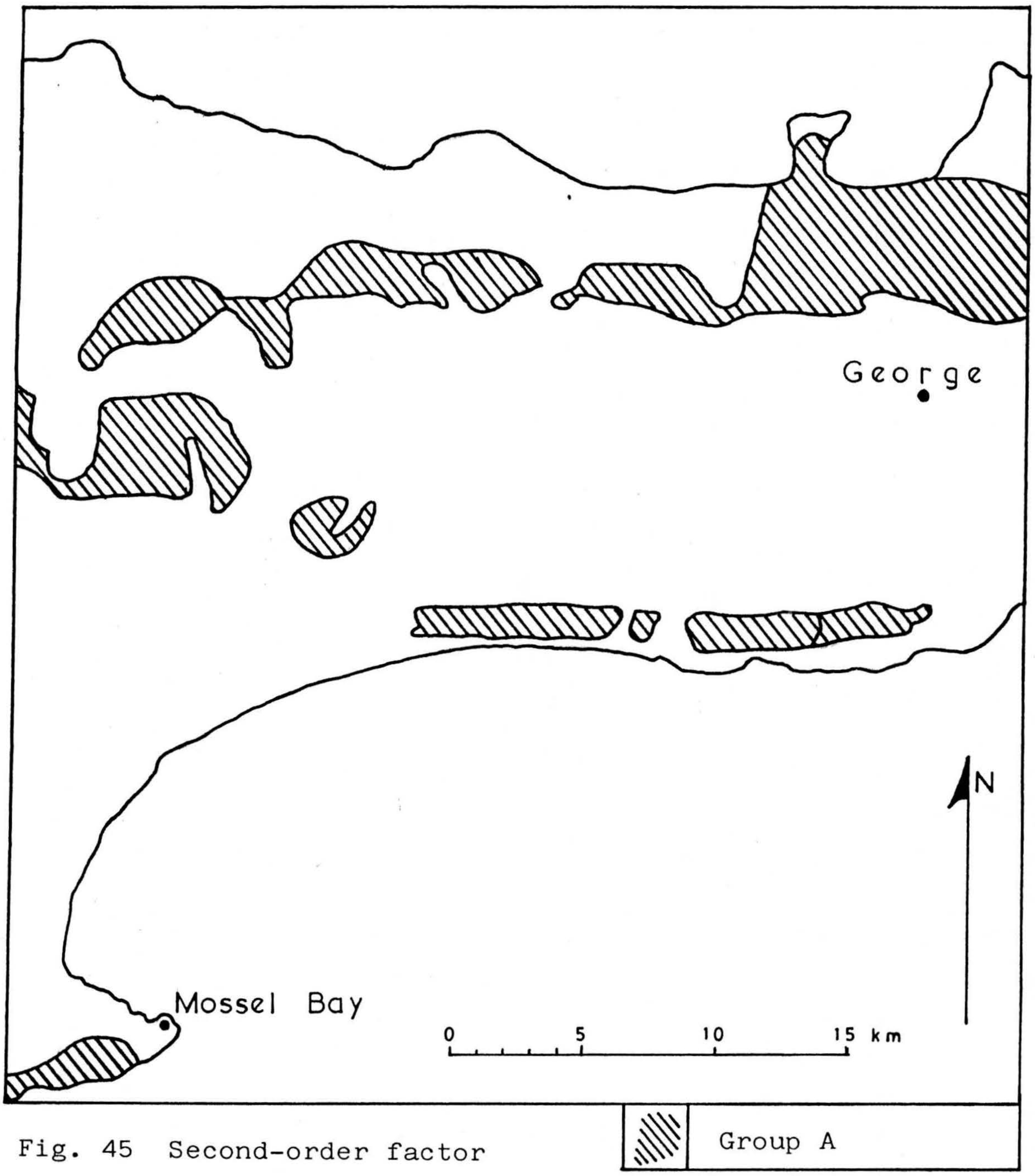

Fig. 45 Second-order factor combinations of the George mountain forests.

Fig. 46 as firm basis and starting point;

An absolute annual rainfall delimitation of 500 mm, thereby excluding potential forest area in the Mossel Bay vicinity;

rock exposure in excess of 50% along the steeper Outeniqua slopes evident on aerial photographs;

the present location pattern of remnant forests;

fynbos colonisation, particularly evident on north-westerly aspects by Protea nitida consociations (mainly outside the study area) and on south-easterly aspects by Widdringtonia nodiflora consociations as a fire-dominated vegetation zone;

forest vegetation trends apparent from western and eastern indigenous forest outliers. There is a distinct mountain forest location pattern noticeable, unassociated with the lower high forest location pattern.

The potential forest area on Fig. 47 is 23 760 ha. The present forest area is 2 960 ha, or 12,5% of the 'potential' estimate. Von Breitenbach [1968(b), p.1.1.3] in a Management Plan of the Groenkop forest (this lies just east of George mountain study area), has drawn a sequence of four maps which feature forest retrogression from 1800 until 1967. Fig. 48 shows Von Breitenbach's estimate of the extent of the forest in the year 1800, with the darker areas representing the 1967 forest location pattern. The forest area lost between 1800 and 1967 amounts to about 50%. Von Breitenbach does, however, not indicate what basis he used to arrive at the forest location pattern of 1800, as portrayed by Fig. 48.

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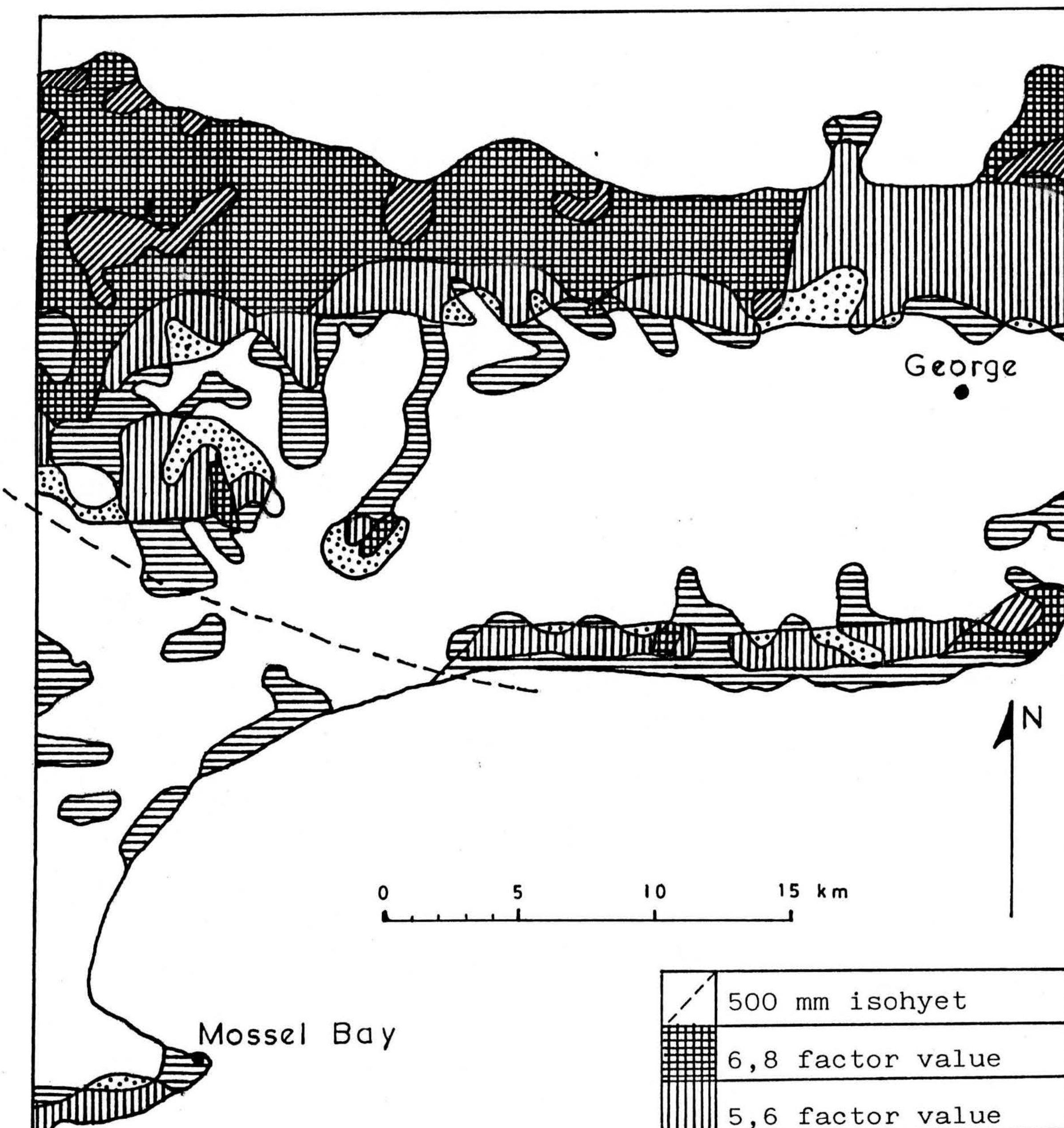

Fig. 46 The main factorial divisions of the George mountain forests.

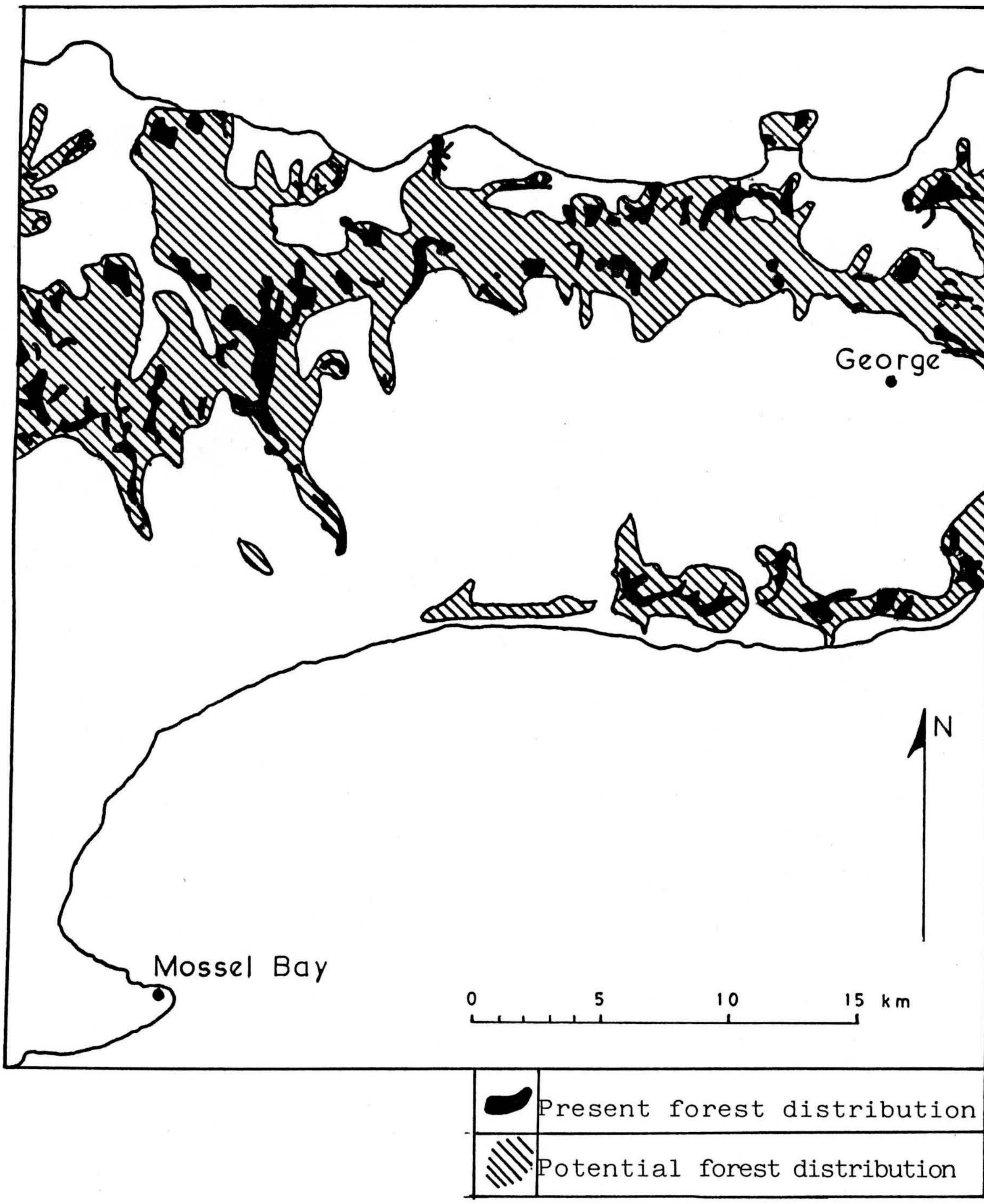

Fig. 47 The potential distribution of the indigenous forests of the Southern Cape based on an eight-factor combination design, the George mountain forests.

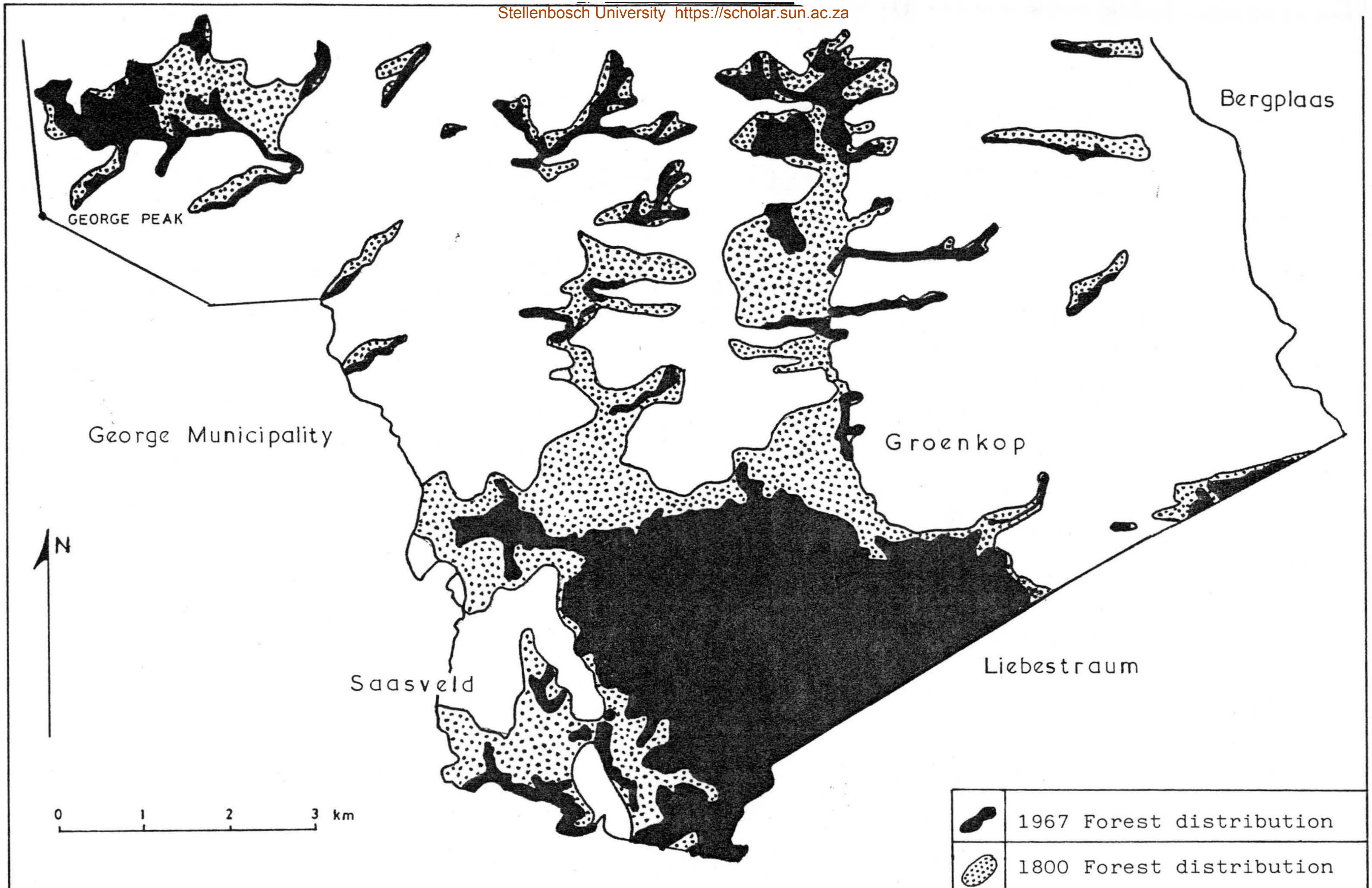

Fig. 48 The present and former distribution of the indigenous forests of the Southern Cape, the Groenkop forest [after Von Breitenbach, 1968(b)].

CHAPTER 8

CONCLUSION

The purpose with this conclusion is to summarise and interpret the results and to arrive at valid scientific conclusions about the value of this study. The aim with this treatise was -

to describe the Southern Cape indigenous forests in their broader regional setting;

to quantify descriptive data and to analyse such data by selected, valid statistical methods;

to explain indigenous forest location patterns with the aid of such descriptive analysis;

to attempt to predict the potential or former areal extent of the indigenous forests.

Each of the above-mentioned aims are briefly accounted for.

8.1 The Descriptive

The indigenous forests have been described in their wider regional setting in the first four chapters, based primarily on information gained from published data. Data is also derived from unpublished sources, particularly data on soils and the economy of the Southern Cape. The extent to which unpublished data is used may be an indicator that the subject matter concerned is currently important and further researched on. This applies particularly to Southern Cape soils, which are currently investigated by various research organisations. The descriptive has however been supplemented by own research as well, in particular -

with the determination of and control over land and forest surface areas (a mapping control design was devised which bridges the descriptive and the experimental/analytical in this regard);

with the consolidation of climatic data, particularly that of precipitation for the study area;

with tree species representation of various different indigenous forest types.

The descriptive sections also feature shortcomings that require possible further research, such as :

an acceptable definition of the term "forest";

a uniform system of classifying different forest types;

indigenous forest areal control uniformity;

plant succession in the forest ecotone; and

more basic quantified data is required on environmental parameters, particularly those of soil and climate in the unpopulated mountains and foothill zones.

8.2 Quantified Data Collection

The value of this treatise is largely centred on the method and the amount of quantified environmental data collected. This is represented in chapters 5 and 6, in part 5.3 for regional data and in part 6.2 for local study data within the three sub-regions George, Knysna and Tsitsikamma. The methods of data collection, based on the use of the 1 : 250 000 scale map with a grid-design of one minute by one minute and 0,5 minute by 0,5 minute quadrats (Buys, 1971), is particularly well-suited for research work over extensive areas. The data collection is furthermore complete, i.e. without any sampling, which enhances its value and potential use. In this study complete data collection facilitated predictions of former forest location.

Of more direct value is the result of the quantification of eight selected environmental physical and human factors, namely:

> two terrain types, emphasising relative relief and terrain ruggedness, precipitation, geological formations, aspect, elevation, human access and the impact of rural population.

Quantification, i.e. data collection, was done for the whole study area of 447 000 ha and its included forest area of 65 000 ha. Each of the factors mentioned was classified into land and forest areal units, on average expressed at between five and six different levels. This quantification must on the one hand be seen as aiding the description of the forests within their regional and local setting, on the other hand it must be viewed as an aid in explaining forest location patterns.

Examples of the importance of descriptive quantification are listed below for purposes of illustrating the value of quantification taken from the broader regional study of chapter 5:

> 41,9% of the study area is located on fairly level terrain (0 to 5°);

only 17,5% of the study area gets annual rainfall in excess of 1 000 mm;

66,8% of the land is located on Table Mountain sandstone;

50% of the land lies below (or above) 300 m altitude;

50% of the land lies within (or outside) readily accessible areas.

Similar quantitive results are available for forest cover, and a combination of the two quantitive criteria provide a broad basis for further evaluation, namely that of a calculated percentage forest cover. The following example is a simplified version of such an evaluation:

The portion of land within the Southern Cape as a whole which features above-average forest cover, is located on land with a 3,5° to 11° slope;

it has an annual rainfall exceeding 800 mm;

it is located on Table Mountain sandstone or shale, on a southerly or easterly aspect;

it lies from 0 to 450 m above sea-level in an area with a rural settlement density of from nil to five buildings per 282 ha.

Quantification of data on the three local levels reveal important anomalies when compared with the regional trend. This is revealed by the following example of the George mountain forests:

The George forests favour much steeper terrain, at altitudes exceeding 300 m, at a lower minimum annual rainfall of only 600 mm and feature above-average forest cover on westerly as well as on southerly and easterly aspects.

8.3 Statistical Data Analysis

Factorial effects are statistically tested and analysed in two ways:

each of the eight factorial effects is tested separately with the aid of linear regression analysis where possible; and interactions of factors are tested by a combination of two groups of four factors each; their effects are tested with the help of multiple variance analysis.

Factorial effects tested by direct linear regression show strong correlation between forest cover and the factors macro-terrain, precipitation, geological formation, aspect and rural settlement ($>$ 95%) at regional level, with only micro-terrain proving insignificant ($<$ 95%). Elevation also proves insignificant when tested by linear regression, however its effect proves highly insignificant with curvilinear regression ($>$95%). On the whole the factorial effects on the three local levels of George, Knysna and Tsitsikamma follow that of the regional trend, with the following exceptions:

the effect of geological formations on forest cover in the George area proves insignificant; that of aspect insignificant in both the George and Tsitsikamma areas; and the effect of rural settlement insignificant for the Tsitsikamma study area.

In the multi-variance analysis of the Group A factors the effects of macro-terrain, precipitation and geological formation on forest cover are significant, with no notable interaction effects on a regional level. The multi-variance analysis on the three local study levels, however reveal marked differences in effect. As far as the Group A factors are concerned, only Knysna follows the regional trend mentioned above. In the George study area geological formations prove significant in effect, as do the interactions of geological formations/macro-terrain and geological formations/accessibility. In the Tsitsikamma all four factors, namely macro-terrain, precipitation, geological formations and accessibility prove highly effectual ($>$ 99%), as do the interaction precipitation geological formations.

The effects of the Group B factors, which are not tested by multi-variance on a regional level, reveal some important anomalies, when they are compared with the simple regression analysis results, and when the effects of the three study areas are compared with one another. Particularly micro-terrain's variance effect is highly significant in all three local study areas; so is the interaction micro-terrain/aspect in the George area, and the interactions between micro-terrain and respectively altitude, altitude/aspect and altitude/aspect/rural settlement ($>$ 95%) in the Tsitsikamma study area. Micro-terrain features an insignificant total effect, when tested by linear regression, which makes the variance effects all the more noteworthy.

Summarising, the statistical methods employed to test the importance of factorial impact, appear to be very expressive and well-suited for the study in hand. The linear regression test applied to each individual factor appears an essential single-factor effect control, but should preferably be expressed more than the five to six levels used in this study, for better effect. Data expression in directly calculated or measured terms (as opposed to the indirect indexes used to mask interactions in multiple regression analyses) also appear ideally suited to control factorial effects. Multi-variance analysis according to the Yates 2^n method is a very suitable tool for geographical studies of this kind on both regional and local bases and should be used more often. The area of a region should preferably not be too large, otherwise the collection of data easily becomes unmanagable, particularly when 0,5 minute quadrat sizes are used. In this particular study the data on surface land area and indigenous forest area has been monitored in about 40 000 small mapping quadrats for a total land area of about 4 500 km^2. This is considered close to the maximum for a study area when using mapping quadrats as a source of quantification.

8.4 Potential Forest Cover

The descriptive portion of this treatise is supplemented and aided considerably by the quantified data collection referred to in par. 8.2. It is considered apt to round off and culminate the statistical analyses, and with that the study as a whole, with a combination design of quantified statistical data and to thereby provide a predicted or potential indigenous forest distribution pattern. This attempt in chapter 7 is based on the direct use of statistical data obtained from the multi-variance analysis of the two by four factorial treatments, based on calculated value effects. This is only undertaken for the George mountain forest study area. The results obtained for this indigenous forest potential areal prediction certainly merit the attempt made. Results show that only one-eighth of the potential forest area is still nowadays forested in the George area. It is regarded likely that seven-eighths of the indigenous forests, or close thereto, were destroyed by human impact during more recent historical times, but that the mountain forests concerned have, even before such times, had to compete against the encroachment pressure of a fire-adapted fynbos vegetation.

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ANNEXURE A.

MULTI-VARIANCE ANALYSIS OF THE THREE LOCAL STUDY AREAS OF THE SOUTHERN CAPE

TABLE A.I GROUP A FACTORS : ANALYSIS OF VARIANCE BY THE YATES 2^n FACTORIAL DESIGN OF THE GEORGE MOUNTAIN FOREST AREA

TREATMENT COMBINATION	RESPONSE (ANGLES)	TREATMENT (1)	(2)	(3)	(4)	EFFECT $\frac{\text{COL. 4}}{8}$	SUM OF SQUARES $\frac{(\text{COL.4})^2}{16}$
i	0	9,1	21,8	72,6	107,7=	Total	-
a	9,1	12,7	50,8	98,1	23,9	2,988	35,701
b	0	21,8	14,6	28,0	- 12,1	- 1,513	9,151
ab	12,7	29,0	83,5	- 4,1	- 15,3	- 1,913	14,631
c	7,9	14,6	21,8	10,8	97,9	12,238	599,026
ac	13,9	0	6,2	- 22,9	- 48,9	- 6,113	149,451
bc	14,4	45,9	14,6	- 2,2	9,9	1,238	6,126
abc	14,6	37,6	- 18,7	- 13,1	6,7	0,838	2,806
d	0	9,1	3,6	29,0	25,5	3,188	40,641
ad	14,6	12,7	7,2	68,9	- 32,1	- 4,013	64,401
bd	0	6,0	- 14,6	- 15,6	- 33,7	- 4,213	70,981
abd	0	0,2	- 8,3	- 33,3	- 10,9	- 1,363	7,426
cd	28,0	14,6	3,6	3,6	39,9	4,988	99,501
acd	17,9	0	- 5,8	6,3	- 17,7	- 2,213	19,581
bcd	23,1	- 10,1	- 14,6	- 9,4	2,7	0,338	0,456
abcd	14,5	- 8,6	1,5	16,1	25,5	3,188	40,641
TOTAL	170,7						1 160,52

Corrected sum of squares:

= (82,81 + 161,29 + 62,41 + 193,21 + 207,36 + 213,16 + 213,16 + 784,00 + 320,41 + 533,61 + 210,25) - 1 821,16

= 1 160,51

TABLE A.2 GROUP A FACTORS : RESULTS OF VARIANCE ANALYSIS OF THE GEORGE MOUNTAIN FOREST AREA

NATURE OF EFFECT	SOURCE OF VARIATION	DEGREE OF FREEDOM	MEAN SQUARE	CONVENTIONAL SIGNIFICANCE LEVEL
Main factors	Terrain (a)	1	35,701	Not significant
	Rainfall(b)	1	9,151	Not significant
	Geology (c)	1	599,026	99% c.l.
	Access (d)	1	40,641	Not significant
Interactions	ab	1	14,631	Not significant
	ac	1	149,451	95% c.l.
	ad	1	64,401	90% c.l.
	bc	1	6,126	Not significant
	bd	1	70,981	90% c.l.
	cd	1	99,501	95% c.l.
Higher order interactions	abc, abd, acd, bcd, abcd	5	14,182 =	Error

For 1 and 5 degrees of feedom:

1% value of F is 16,30

5% value of F is 6,61

10% value of F is 4,06

therefore -

99% confidence level = 16,30 x 14,182 = 231,167

95% confidence level = 6,61 x 14,182 = 93,743

90% confidence level = 4,06 x 14,182 = 57,579

TABLE A.3 GROUP B FACTORS : ANALYSIS OF VARIANCE BY THE YATES 2^n FACTORIAL DESIGN OF THE GEORGE MOUNTAIN FOREST AREA

TREATMENT COMBINATION	RESPONSE (ANGLES)	TREATMENT				EFFECT $\frac{\text{COL. 4}}{8}$	SUM OF SQUARES $\frac{(\text{COL. 4})^2}{16}$
		(1)	(2)	(3)	(4)		
i	4,1	4,1	4,1	40,7	98,2 =	Total	-
a	0	0	36,6	57,5	61,8	7,725	238,703
b	0	14,7	25,2	32,5	- 1,2	- 0,150	0,090
ab	0	21,9	32,3	29,3	- 6,8	- 0,850	2,890
c	0	14,7	- 4,1	3,1	39,6	4,950	98,010
ac	14,7	10,5	36,6	- 4,3	76,0	9,500	361,000
bc	0	16,2	- 3,0	11,3	15,4	1,925	14,823
abc	21,9	16,1	32,3	- 18,1	21,0	2,625	27,563
d	3,6	- 4,1	- 4,1	32,5	16,8	2,100	17,640
ad	11,1	0	7,2	7,1	- 3,2	- 0,400	0,640
bd	10,5	14,7	- 4,2	40,7	- 7,4	- 0,925	3,423
abd	0	21,9	- 0,1	35,3	- 29,4	- 3,675	54,023
cd	0	7,5	4,1	11,3	- 25,4	- 3,175	40,323
acd	16,2	- 10,5	7,2	4,1	- 5,4	- 0,675	1,823
bcd	0	16,2	- 18,0	3,1	- 7,2	- 0,900	3,240
abcd	16,1	16,1	- 0,1	17,9	14,8	1,850	13,690
TOTAL	98,2						877,881

Corrected sum of squares: = (1 480,58) - (602,703)

= 877,877
=======

TABLE A.4 GROUP B FACTORS : RESULTS OF VARIANCE ANALYSIS OF THE GEORGE MOUNTAIN FOREST AREA

NATURE OF EFFECT	SOURCE OF VARIATION	DEGREE OF FREEDOM	MEAN SQUARE	CONVENTIONAL SIGNIFICANCE LEVEL
Main factors	Terrain (a)	1	238,703	95% c.l.
	Altitude (b)	1	0,090	Not significant
	Aspect (c)	1	98,010	90% c.l.
	Settle-ment (d)	1	17,640	Not significant
Interactions	ab	1	2,890	Not significant
	ac	1	361,000	99% c.l.
	ad	1	0,640	Not significant
	bc	1	14,823	Not significant
	bd	1	3,423	Not significant
	cd	1	40,323	Not significant
Higher order interactions	abc, abd, acd, bcd, abcd	5	20,068	= Error

For 1 and 5 degrees freedom:

99% confidence level = 16,30 x 20,068 = 327,108
95% confidence level = 6,61 x 20,068 = 132,649
90% confidence level = 4,06 x 20,068 = 81,476

TABLE A.5 GROUP A FACTORS : ANALYSIS OF VARIANCE BY THE YATES 2^n FACTORIAL DESIGN OF THE KNYSNA FOREST AREA

TREATMENT COMBINATION	RESPONSE (ANGLES)	TREATMENT (1)	(2)	(3)	(4)	EFFECT $\frac{\text{COL. 4}}{8}$	SUM OF SQUARES $\frac{(\text{COL. 4})^2}{16}$
i	0	7,7	25,6	97,9	196,4 =	Total	-
a	7,7	17,9	72,3	98,5	71,0	8,875	315,063
b	0	8,2	31,6	25,7	145,6	18,200	1324,960
ab	17,9	64,1	66,9	45,3	57,0	7,125	203,063
c	4,1	0	25,6	66,1	82,0	10,250	420,250
ac	4,1	31,6	0,1	79,5	- 43,4	- 5,425	117,723
bc	32,0	9,5	31,6	10,3	62,0	7,750	240,250
abc	32,1	57,4	13,7	46,7	- 26,6	- 3,325	44,223
d	0	7,7	10,2	46,7	0,6	0,075	0,023
ad	0	17,9	55,9	35,3	19,6	2,450	24,010
bd	0	0	31,6	- 25,5	13,4	1,675	11,223
abd	31,6	0,1	47,9	- 17,9	36,4	4,550	82,810
cd	5,1	0	10,2	45,7	- 11,4	- 1,425	8,123
acd	4,4	31,6	0,1	16,3	7,6	0,950	3,610
bcd	21,5	- 0,7	31,6	- 10,1	- 29,4	- 3,675	54,023
abcd	35,9	14,4	15,1	- 16,5	- 6,4	- 0,800	2,560
TOTAL	196,4						2851,914

Corrected sum of squares = (5 262,72) - (2 410,81)

= 2 851,91

TABLE A.6 GROUP A FACTORS : RESULTS OF VARIANCE ANALYSIS OF THE KNYSNA FOREST AREA

NATURE OF EFFECT	SOURCE OF VARIATION	DEGREE OF FREEDOM	MEAN SQUARE	CONVENTIONAL SIGNIFICANCE LEVEL
Main factors	Terrain (a)	1	315,063	95% c.l.
	Rainfall(b)	1	1324,960	99% c.l.
	Geology (c)	1	420,250	95% c.l.
	Access (d)	1	0,023	Not significant
Interactions	ab	1	203,063	90% c.l.
	ac	1	117,723	Not significant
	ad	1	24,010	Not significant
	bc	1	240,250	90% c.l.
	bd	1	11,223	Not significant
	cd	1	8,123	Not significant
Higher order interactions	abc, abd, acd, bcd, abcd	5	37,445	= Error

For 1 and 5 degrees of freedom:

99% confidence level = 16,30 x 37,445 = 610,354

95% confidence level = 6,61 x 37,445 = 247,511

90% confidence level = 4,06 x 37,445 = 152,027

TABLE A.7 GROUP B FACTORS : ANALYSIS OF VARIANCE BY THE YATES 2^n FACTORIAL DESIGN OF THE KNYSNA FOREST AREA

TREATMENT COMBINATION	RESPONSE (ANGLES)	TREATMENT (1)	(2)	(3)	(4)	EFFECT $\frac{\text{COL. 4}}{8}$	SUM OF SQUARES $\frac{(\text{COL.4})^2}{16}$
i	4,8	16,5	57,8	145,5	344,9 =	Total	-
a	11,7	41,3	87,7	199,4	81,7	10,213	417,181
b	18,1	37,4	95,7	42,3	101,7	12,713	646,431
ab	23,2	50,3	103,7	39,4	16,5	2,063	17,016
c	14,2	33,3	12,0	37,7	37,9	4,738	89,776
ac	23,2	62,4	30,3	64,0	41,9	5,238	109,726
bc	14,5	34,4	7,9	10,5	6,1	0,763	2,326
abc	35,8	69,3	31,5	6,0	35,9	4,488	80,551
d	12,7	6,9	24,8	29,9	53,9	6,738	181,576
ad	20,6	5,1	12,9	8,0	- 2,9	-0,363	0,526
bd	31,2	9,0	29,1	18,3	26,3	3,288	43,231
abd	31,2	21,3	34,9	23,6	- 4,5	-0,563	1,266
cd	12,8	7,9	- 1,8	-11,9	- 21,9	-2,738	29,976
acd	21,6	0	12,3	5,8	5,3	0,663	1,756
bcd	23,3	8,8	- 7,9	14,1	17,7	2,213	19,581
abcd	46,0	22,7	13,9	21,8	7,7	0,963	3,706
TOTAL	344,9						1644,625

Corrected sum of squares = (9 079,37) - (7 434,75)

= 1 644,62

TABLE A.8 GROUP B FACTORS : RESULTS OF VARIANCE ANALYSIS OF THE KNYSNA FOREST AREA

NATURE OF EFFECT	SOURCE OF VARIATION	DEGREE OF FREEDOM	MEAN SQUARE	CONVENTIONAL SIGNIFICANCE LEVEL
Main factors	Terrain (a)	1	417,181	99% c.l.
	Altitude (b)	1	646,431	99% c.l.
	Aspect (c)	1	89,776	90% c.l.
	Settlement(d)	1	181,576	95% c.l.
Interactions	ab	1	17,016	Not significant
	ac	1	109,726	90% c.l.
	ad	1	0,526	Not significant
	bc	1	2,326	Not significant
	bd	1	43,231	Not significant
	cd	1	29,976	Not significant
Higher order interactions	abc, abd, acd, bcd, abcd	5	21,372	= Error

For 1 and 5 degrees of freedom:

99% confidence level = 16,30 x 21,372 = 348,364

95% confidence level = 6,61 x 21,372 = 141,209

90% confidence level = 4,06 x 21,372 = 86,770

TABLE A.9 GROUP A FACTORS : ANALYSIS OF VARIANCE BY THE YATES 2^n FACTORIAL DESIGN OF THE TSITSIKAMMA FOREST AREA

TREATMENT COMBINATION	RESPONSE (ANGLES)	TREATMENT				EFFECT $\frac{\text{COL. 4}}{8}$	SUM OF SQUARES $\frac{(\text{COL. 4})^2}{16}$
		(1)	(2)	(3)	(4)		
i	0	0	0	32,3	125,9=	Total	-
a	0	0	32,3	93,6	58,7	7,338	215,356
b	0	0	26,0	12,1	73,9	9,238	341,326
ab	0	32,3	67,6	46,6	6,7	0,838	2,806
c	0	13,1	0	32,3	73,9	9,238	341,326
ac	0	12,9	12,1	41,6	6,7	0,838	2,806
bc	10,1	12,9	26,0	12,1	74,3	9,288	345,031
abc	22,2	54,7	20,6	- 5,4	7,1	0,888	3,151
d	0	0	0	32,3	61,3	7,663	234,856
ad	13,1	0	32,3	41,6	34,5	4,313	74,391
bd	0	0	- 0,2	12,1	9,3	1,163	5,406
abd	12,9	12,1	41,8	- 5,4	- 17,5	- 2,188	19,141
cd	0	13,1	0	32,3	9,3	1,163	5,406
acd	12,9	12,9	12,1	42,0	- 17,5	- 2,188	19,141
bcd	23,5	12,9	- 0,2	12,1	9,7	1,213	5,881
abcd	31,2	7,7	- 5,2	- 5,0	- 17,1	- 2,138	18,276
TOTAL	125,9						1634,300

Corrected sum of squares = (2 624,97) - (990,676)

= 1 634,29

TABLE A.10 GROUP A FACTORS : RESULTS OF VARIANCE ANALYSIS OF THE TSITSIKAMMA FOREST AREA

NATURE OF EFFECT	SOURCE OF VARIATION	DEGREE OF FREEDOM	MEAN SQUARE	CONVENTIONAL SIGNIFICANCE LEVEL
Main factors	Terrain (a)	1	215,356	99% c.l.
	Rainfall (b)	1	341,326	99% c.l.
	Geology (c)	1	341,326	99% c.l.
	Access (d)	1	234,856	99% c.l.
Interactions	ab	1	2,806	Not significant
	ac	1	2,806	Not significant
	ad	1	74,391	90% c.l.
	bc	1	345,031	99% c.l.
	bd	1	5,406	Not significant
	cd	1	5,406	Not significant
Higher order interactions	abc, abd, acd, bcd, abcd	5	13,118	= Error

For 1 and 5 degrees of freedom:

99% confidence level = 16,30 x 13,118 = 213,823

95% confidence level = 6,61 x 13,118 = 86,710

90% confidence level = 4,06 x 13,118 = 53,259

TABLE A.11 GROUP B FACTORS : ANALYSIS OF VARIANCE BY THE YATES 2^n FACTORIAL DESIGN OF THE TSITSIKAMMA FOREST AREA

TREATMENT COMBINATION	RESPONSE (ANGLES)	TREATMENT (1)	(2)	(3)	(4)	EFFECT $\frac{\text{COL. 4}}{8}$	SUM OF SQUARES $\frac{(\text{COL. 4})^2}{16}$
i	8,5	20,6	70,6	164,3	303,5 =	Total	-
a	12,1	50,0	93,7	139,2	76,7	9,588	367,681
b	17,2	36,1	58,3	46,3	64,9	8,113	263,251
ab	32,8	57,6	80,9	30,4	63,7	7,963	253,606
c	11,4	25,7	19,2	50,9	45,7	5,713	130,531
ac	24,7	32,6	27,1	14,0	24,5	3,063	37,516
bc	21,9	36,9	6,9	12,5	- 7,7	- 0,963	3,706
abc	35,7	44,0	23,5	51,2	- 76,9	- 9,613	369,601
d	25,7	3,6	29,4	23,1	- 25,1	- 3,138	39,376
ad	0	15,6	21,5	22,6	- 15,9	- 1,988	15,801
bd	0	13,3	6,9	7,9	- 36,9	- 4,613	85,101
abd	32,6	13,8	7,1	16,6	38,7	4,838	93,606
cd	10,8	- 25,7	12,0	- 7,9	- 0,5	- 0,063	0,016
acd	26,1	32,6	0,5	0,2	8,7	1,088	4,731
bcd	17,9	15,3	58,3	- 11,5	8,1	1,013	4,101
abcd	26,1	8,2	- 7,1	- 65,4	- 53,9	- 6,738	181,576
TOTAL	303,5						1850,200

Corrected sum of squares = (7 607,21) - (5 757,02)

= 1 850,19

TABLE A.12 GROUP B FACTORS : RESULTS OF VARIANCE ANALYSIS OF THE TSITSIKAMMA FOREST AREA

NATURE OF EFFECTS	SOURCE OF VARIATION	DEGREE OF FREEDOM	MEAN SQUARE	CONVENTIONAL SIGNIFICANCE LEVEL
Main factors	Terrain (a)	1	367,681	99% c.l.
	Altitude (b)	1	263,251	95% c.l.
	Aspect (c)	1	130,531	95% c.l.
	Settlement (d)	1	39,376	Not significant
Interactions	ab	1	253,606	95% c.l.
Higher order Interactions	abc,	1	369,601	99% c.l.
	abd,	1	93,606	90% c.l.
	abcd	1	181,576	95% c.l.
Interactions and higher order inter-actions	ac, ad, bc, bd, cd, acd, bcd	7	21,567	= Error

For 1 and 7 degrees of freedom:

99% confidence level = 12,25 x 21,567 = 264,196
95% confidence level = 5,59 x 21,567 = 120,560
90% confidence level = 3,59 x 21,567 = 77,426